Best Practice Description Document

Creating a weekly Harmful Algal Bloom bulletin

1.0

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<tr><td colspan="2">Abstract
This document describes the procedural steps in creating an information product focused on toxic and harmful phytoplankton. The product is an online Harmful Algal Bloom (HAB) bulletin for aquaculturists, who can face serious operational challenges in the days after a HAB event. Data from satellite, numerical hydrodynamic models and In-situ ocean observations are organised and presented into visual information products. These products are enhanced through local expert evaluation and their interpretation is summarised in the bulletin. This document aims to provide both process overviews (the “what” of the Best Practice in producing the bulletins) and detail procedures (the “how” of the Best Practice”) so that the bulletins may be replicated in other geographic regions.</td></tr>
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[1] http://www.goosocean.org/index.php?option=com_oe&task=viewDocumentRecord&docID=17507
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[11] http://www.goosocean.org/index.php?option=com_oe&task=viewDocumentRecord&docID=17472

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Table of Acronyms

ASP	**A**mnesic **S**hellfish **P**oisoning
AZP	**A**zaspiracid **S**hellfish **P**oisoning
BIM	Sea Fisheries Board – **B**ord **I**ascaigh **M**hara
CA	**C**ompetent **A**uthority
CMEMS	**C**opernicus **M**arine **E**nvironmental **M**onitoring **S**ervice (DG Growth)
CoP	**C**ode **o**f **P**ractice
CRL	**C**ommunity **R**eference **L**aboratory
DSP	**D**iarrhetic **S**hellfish **P**oisoning (part of the lipophilic group)
EO	**E**arth **O**bservation
EOV	**E**ssential **O**cean **V**ariable
EPA	**E**nvironmental **P**rotection **A**gency
EU	**E**uropean **U**nion
EURL	**EU** **R**eference **L**aboratory
FSAI	**F**ood **S**afety **A**uthority of **I**reland
HAB(s)	**H**armful **A**lgal **B**loom(s)
HPLC	**H**igh **P**erformance **L**iquid **C**hromatography
HPLC DAD	**H**igh **P**erformance **L**iquid **C**hromatography with **D**iode **A**rray **D**etection
HSE	**H**ealth **S**ervice **E**xecutive
IFPEA	**I**rish **F**ish **P**rocessors and **E**xporters **A**ssociation
IPI	**I**nternational **P**hytoplankton **I**ntercomparison
ISA	**I**rish **S**hellfish **A**ssociation
ISO	**I**nternational **O**rganization for **S**tandardization
LCMS-MS/MS	**L**iquid **C**hromatography coupled **M**ass **S**pectrometry / **M**ass **S**pectrometry
LT	**L**ipophilic **T**oxins
MBA	**M**ouse **B**io**A**ssay
MI	**M**arine **I**nstitute
MSSC	**M**olluscan **S**hellfish **S**afety **C**ommittee
NMP	**N**ational **M**onitoring **P**rogramme
NOAA	**N**ational **O**ceanic and **A**tmospheric **A**dministration
PSP	**P**aralytic **S**hellfish **P**oisoning
ROMS	**R**egional **O**cean **M**odelling **S**ystem
SFPA	**S**ea **F**isheries **P**rotection **A**uthority
SST	**S**ea **S**urface **T**emperature
THREDDS	**Th**ematic **R**eal-time **E**nvironmental **D**istributed **D**ata **S**ervices
UNESCO-IOC	**U**nited **N**ations **E**ducational, **S**cientific and **C**ultural **O**rganisation **I**ntergovernmental **O**ceanographic **C**ommission

Glossary of terms

Competent Authority	An authority which is competent to carry out checks, as defined by EU Legislation.
HAB Bulletins	Weekly HAB bulletins are compiled and published by the Irish Marine Institute as an assistance information tool to industry. The bulletins contain a number of collated data products from the historical and current biotoxin and phytoplankton profiles, along with oceanographic *In-situ* and modelled data products used as a predictive forecasting tool.
HABs Database	All sample details and associated results from the Irish Shellfish Monitoring Programme for biotoxins and phytoplankton samples are inputted into the Marine Institute Harmful Algal Blooms (HABs) Database. The results are published online at www.marine.ie/habs.
HABs	Harmful Algal Blooms are biological events caused by a small number of phytoplankton species. There are two main types of HABs • High biomass blooms that produce biotoxins harmful to marine fauna and farmed fish/shellfish and/or cause anoxic conditions to occur resulting in environmental conditions that are unfavourable to marine life and farmed species. Blooms can occur naturally, although in some parts of the world such as Hong Kong and parts of the USA the proliferation of certain HAB species have been attributed to anthropogenic nutrient enrichment. • Low biomass blooms that produce biotoxins can accumulate in shellfish and throughout marine food-webs. If consumed by humans a variety of illnesses can result, the severity of which depends on the causative organisms and the biotoxins they produce.
International Phytoplankton Intercomparison	Managed by the Irish Marine Institute in cooperation with UNESCO-IOC IPI is a partnership of agencies, quality control entities and organisations with interest in phytoplankton monitoring and quality control.
Phytoplankton	Microscopic plants that live in water.

1. *Ocean Observing Value Chain*

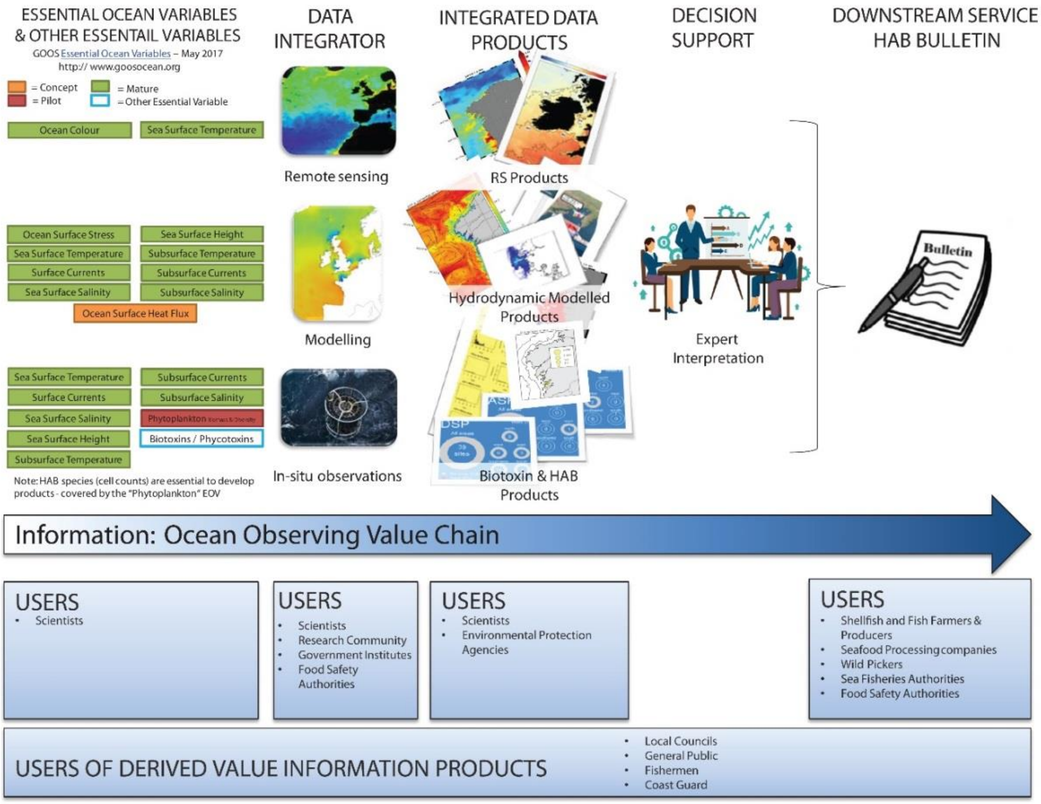


Figure 1. Harmful Algal Bloom Bulletin Production: application of knowledge along the value chain from In-situ, satellite and modelled data, integrated data information products through to the knowledge targeted product i.e. HAB bulletin production. Some of the current "Users" of the products along the chain are identified. The development of a HAB bulleting follows the method outlined in "A Framework for Ocean Observing" (Lindstrom et al. 2012).

2. Phytoplankton bloom types

High biomass phytoplankton blooms: The colour of a phytoplankton high biomass bloom can vary considerably and depends on the density (cells/Litre) of the causative organism in the water. The bloom's colour will change across its spatial extent, with most blooms exhibiting darker colours towards the centre of the bloom patch. Cells with highly packed chloroplasts will usually be darker in colour while senescent (aging or old) cells will have a paler colour. Subsurface blooms also occur and are not usually visible from the surface, although if the bloom is positioned only a few metres below the sea surface, cells might rise to the surface in the wake of a passing vessel. High biomass phytoplankton blooms are, for the most part, beneficial to ecosystems. However, some monospecific blooms can cause harm. Examples of marine phytoplankton found in Irish waters that have the potential to proliferate into what is often referred to as "red tides" include the dinoflagellates *Karenia mikimotoi* with a history of causing fish and benthic community mortalities (brown-rust colour), *Ceratium furca* (yellowish-brown colour), *Prorocentrum* spp. (reddish-brown or mahogany colour), *Askashiwo sanguinea* (rusty-orange colour), *Glenodinium* foliaceum (rusty-brown colour), *Noctiluca scintillans,* (rusty-orange colour), *Dinophysis* spp., A*lexandrium* spp., *Scrippsiella* spp., *Polykrikos* spp., *Lingulodinium polyedra* (all red), Bioluminescent dinoflagellate blooms, the diatoms (blooms commonly yellow-brown to dark-brown colour, rarely pale green) e.g. *Rhizosolenia stolterforthii* (dark brown-yellow brown, senescent cells are pale brown-white colour), zooplankton such the ciliate *Myrionecta rubra* originally *Mesodinium rubrum* (red or yellow), the coccolithophorids - typically *Emiliania huxleyi* (mirror like water at beginning of bloom, turns into a milky white colour when in full bloom) and foams by the prymnesiophyte, *Phaeocystis*. Figure 2 below presents some internationally taken photos of high biomass phytoplankton blooms visible in surface waters. Note: one of the images is a chalk experiment that mimics the colour of a coccolithophorid bloom. Water discolouration is not always caused by plankton.

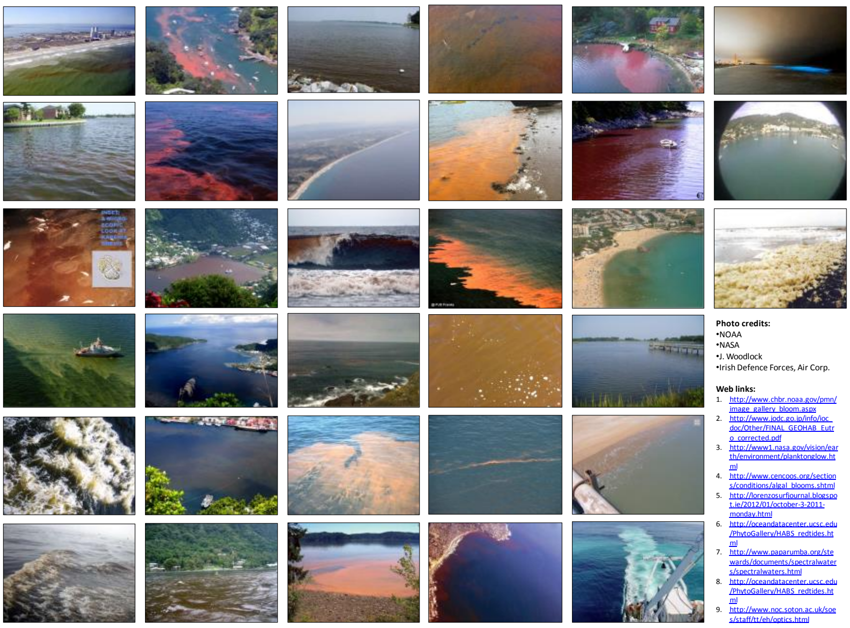
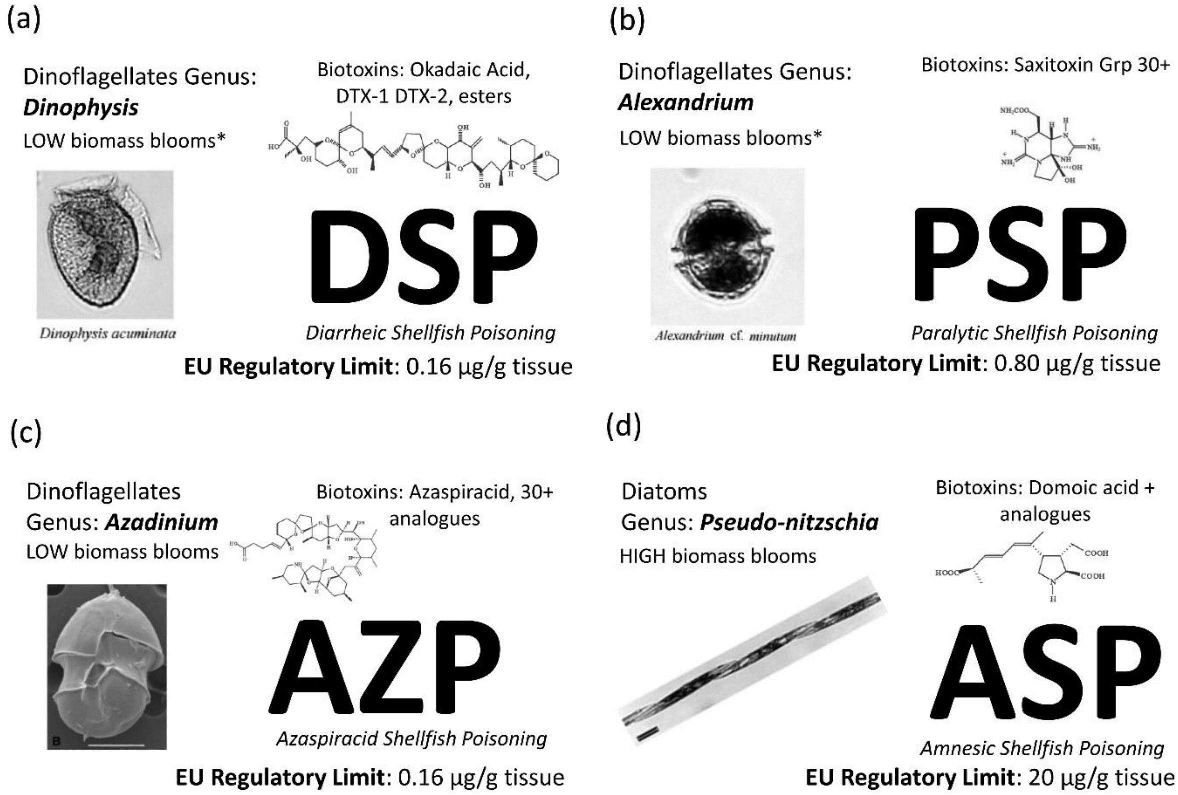


Figure 2. High biomass blooms in marine waters. These blooms cause water to discolour and are sometimes referred to as "red tides" although they are not always red in colour and not always harmful. Blooms can harm marine life although only some phytoplankton species associated with negative effects on the marine environment. Photographic sources NOAA[12]*;* JODC[13]; NASA[14];

[12] https://products.coastalscience.noaa.gov/pmn/image_gallery_bloom.aspx
[13] http://www.jodc.go.jp/jodcweb/info/ioc_doc/Other/FINAL_GEOHAB_Eutro_corrected.pdf
[14] https://www.nasa.gov/vision/earth/environment/planktonglow.html

CENCOOS[15]; Lorenzo's Surf Journal[16]; University of California, Santa Cruz[17, 18]; Christian Gronau[19]; School of Ocean and Earth Sciences, Southampton University[20].

Toxic HABs: In Ireland, the majority of toxic HABs are caused by low biomass blooms (Figure 3a, b, c). For example, the dinoflagellate genus *Dinophysis* can contaminate Irish shellfish with the biotoxin Okadaic Acid at very low cell levels (~ 200 cells/Litre). Figure 3 below presents the most commonly found biotoxins in Irish waters and their associative phytoplankton producers.



* Low biomass blooms are typical in Irish Bays. However, in other parts of the world these organisms are recoded as high biomass bloom formers e.g. *Alexandrium* species form dense monospecific blooms in NW Atlantic waters.

Figure 3. Biotoxins most relevant to the Irish shellfish industry cause (a) Diarrheic Shellfish Poisoning (DSP), (b) Paralytic Shellfish Poisoning (PSP), (c) Azaspiracid Shellfish Poisoning (AZP) and (d) Amnesic Shellfish Poisoning (ASP) in humans if contaminated shellfish are consumed. These biotoxin groups are detected in Irish waters at different times of the year when the causative phytoplankton are blooming. Low biomass blooms are the most common cause of toxic events in Ireland caused by the dinoflagellates (a) Dinophysis spp. (b) Alexandrium spp. and (c) Azadinium spp. For more information on toxic and harmful phytoplankton species, please refer to The IOC-UNESCO Taxonomic Reference List of Harmful Micro Algae[21].

[15] https://www.cencoos.org/learn/blooms
[16] http://lorenzosurfjournal.blogspot.ie/2012/01/october-3-2011-monday.html
[17] http://oceandatacenter.ucsc.edu/PhytoGallery/phytolist.html
[18] http://oceandatacenter.ucsc.edu/PhytoGallery/HABS_redtides.html
[19] http://www.paparumba.org/stewards/documents/spectralwaters/spectralwaters.html
[20] https://web.archive.org/web/20170628161551/www.noc.soton.ac.uk/soes/staff/tt/eh/optics.html
[21] http://www.marinespecies.org/hab/

3. Introduction

The EU produces ~ 1.25 million tonnes in aquaculture products annually. Aquaculture is considered an important marine food source and has positive impacts on the local economies in rural marine communities. However, Harmful Algal Blooms or HABs can severely impact finfish and shellfish aquaculture and are considered a serious economic risk to seafood businesses. Detrimental effects can occur in one of two ways. The first relates to closure of farms when HAB biotoxins, usually produced by low biomass phytoplankton species, accumulate in shellfish to levels harmful or lethal to humans if consumed. Some phytoplankton species can bloom to extraordinary cell levels that result in discoloured water. These high biomass blooms, sometimes referred to colloquially as "red tides" can endanger marine life by: clogging the gills of caged fish unable to avoid the hazard by swimming out of harm's way; producing ichtyotoxins, toxic to fish and other marine organisms; and suffocating marine life, pelagic and benthic, when blooms subside and bacterial activity and respiration increases dramatically over a short period of time. Today, advances in seafood safety practices and legal requirements to safeguard seafood products at national and EU level now effectively guarantee seafood to be safe for human consumption. However, this does not protect the industry against loss of farmed stock when safety regulations require protracted harvesting closures (for example, the risk that heavy shellfish will fall off longline mussel cultures) and during HAB events that kill caged fish.

Harmful Algal Blooms are recognised globally as a marine hazard with yearly costs to fisheries and shellfisheries at billions of Euros per annum; conservatively estimated at USA $ 95 million, Europe > € 800 million, Japan US $ 1 billion (Bernard *et al.* 2014). In Ireland, biotoxins produced by phytoplankton species are ranked as a top issue in terms of industry challenges (PricewaterhouseCoopers, 2006). The annual estimate of the economic loss due to toxic HABs in SW Ireland is ~ € 530,000 (Cusack *et al.* 2016). Fish farms in the area also suffer when high biomass blooms, that produce ichthyotoxins, such as the dinoflagellate *Karenia mikimotoi* arrive into bays e.g. cessation of trout farming in SW Ireland in the early 1980s when HABs were frequent.

Today, the Aquaculture industry want clear information on the current and expected HAB hazard in nearby marine areas to help harvesting related decisions and an early warning to allow responsive decisions to the weekly operations e.g. rapid harvest before toxic blooms close production areas in the Bay, allow the transport of finfish away from high biomass blooms or allow time to install preventative measures, such as bubble currents to disperse the HAB threat to caged fish.

A HAB bulletin should provide useful information that can assist regulatory, public and state bodies and commercial seafood groups. The main aim of the bulletin is to support business decision making towards HAB risk reduction. The Irish HAB bulletin is published on the web once a week (usually on a Tuesday[22]). Figure 4 below shows the HAB summary page in the bulletin.

[22] A HAB bulletin may be seen at https://www.marine.ie/Home/site-area/data-services/interactive-maps/weekly-hab-bulletin

HAB Bulletin [status of harmful and toxic algae]

Week 5 Jan 28 – Feb 03rd 2017

Week runs from Sunday to Saturday

Ireland: **Predictions**

ASP event: Low - steady
AZP event: **High** (poss. moderate) - constant fluctuation
DSP event: Low - steady
PSP event: Low to very low - steady (site specific)

NMP Current closures			
ASP	AZP	DSP	PSP
0	0	0	0

General – WK 5 -No significant change in any of the species or toxin levels this week .The current light regime and weather conditions would not be conducive to high growth.

ASP: No significant change in last 3 months – cell levels are very low with a very slow rate of growth, and no immediate toxin issues indicated. No significant toxic species/toxin currently present. A seasonal slow increase over the next few week would be the norm for growth patterns in suitable environmental conditions.

AZP: ***High precaution level*** is still advised with this difficult species as a necessary precaution. Currently low to negligible toxin levels. Toxin levels may be showing the start od a declining trend but generally continued fluctuations in presence and levels of cells and toxins. Issues with this toxin can occur suddenly and acutely .

DSP: Low - 3 months of a steady tend with all sites currently indicating continued traditional low likelihood of any immediate DSP treat . This is based on steady consistent low to negligible cells levels, historical trends and current environmental conditions.

PSP: Same as 3 months- Stable seasonal pattern of very low cell levels and low likelihood of issues establishing .Current environmental conditions and patterns are not indicated to be favourable for bloom issues .

Blooms: **No current significant issues recorded with any of the historically occurring problematic species.** Any unusual water discoloration should be noted and regional labs contacted if concerned /regarding possible need for additional sampling. All feedback is welcome at Joe.Silke@Marine.ie .

Figure 4. Front page example in the current version of the Irish HAB bulletin, for the week of 28th January to 3rd February 2017.

There are a wide range of HAB bulletin stakeholders, these are listed below:

- Aquaculture industry
  - Shellfish and fish farmers
  - Shellfish and fish producers
  - Harvesters and Seafood processing companies
  - Irish Farmers Association (IFA) Aquaculture
  - Irish Salmon Growers' Association Ltd. (ISGA)
  - Irish Shellfish Association (ISA)
- Wild pickers
- Scientists
  - Research Community
  - Government
- Department of Agriculture, Food & the Marine
- Molluscan Shellfish Safety Committee
- Government Institutes / Agencies / Authorities
  - Marine institute
  - Environmental Protection Agency
  - Food Safety Authorities - Food Safety Authority of Ireland
  - Sea Fisheries Board – Bord Iascaigh Mhara
  - Sea fisheries authorities – Sea Fisheries Protection Authority

The Irish Molluscan Shellfish Safety Committee[23] (MSSC), established in 2001, is chaired by the Food Safety Authority of Ireland[24] (FSAI) and includes representation from The Sea Fishery Protection Authority[25] (SFPA), the Marine Institute[26] (MI), Irish Water / Uisce Éireann[27], the Irish Sea Fisheries Board / Bord Iascaigh Mhara[28] (BIM), the Health Service Executive[29] (HSE), the Environmental Protection Agency[30] (EPA) and industry representatives (e.g. Irish Shellfish Association[31]) and processors (e.g. Irish Fish Processors and Exporters Association; IFPEA). This MSSC provides a forum for all stakeholders from regulators, scientists and industry to discuss current progress and issues related to seafood safety. They meet once every three months. The FSAI in collaboration with groups listed above have put in place a Code of Practice[32] (CoP) for the Irish Shellfish Monitoring Programme (Biotoxins). The CoP provides a link to the weekly HAB bulletin[33] to support primary producers and processors with a big picture of recent HAB and biotoxin developments around the Irish coast. To facilitate End-User feedback on the weekly HAB Bulletin content, a contact email address for the MI Shellfish Safety Section Manager is provided on the first page of the bulletin with text that invites feedback on the bulletin. This facilitates the feedback loop to aid improvements of bulletin content i.e. End-Users can provide constructively critical reviews of information products in the bulletin and submit requests to develop new useful data products. Since 2000, the "Irish Shellfish Safety Workshop" (previously the Irish Marine Biotoxin Science Workshop) has brought stakeholders together to discuss biotoxin issues in Ireland. The forum is attended by industry, scientists, regulators, government department officials and other government agency representatives with a purpose to take stock of progress, discuss issues and identify options to fine-tune / improve the current system while continuing to adhere to safety regulations imposed by the EU and FSAI. At the meetings, results from the national phytoplankton and biotoxin shellfish monitoring programmes, new developments in scientific research and any changes to existing regulations and/or introduction of new regulations are presented and discussed. The workshops also provide a platform for industry to present their views via oral presentations and discussions, and facilitates a mechanism to allow feedback from the aquaculture sector on recent developments. Workshop proceedings can be downloaded from the MI open access repository[34]. Irish scientists, regulators and industry also attend and present at international conferences e.g. the International Conference on Molluscan Shellfish Safety[35] (ICMSS) and the International Conferences on Harmful Algae[36] (IHABC).

[23] https://www.fsai.ie/about_us/industry_fora/mssc.html
[24] http://www.fsai.ie/
[25] http://www.sfpa.ie/
[26] http://www.marine.ie/
[27] https://www.water.ie/
[28] http://www.bim.ie/
[29] http://www.hse.ie/eng/
[30] https://www.epa.ie/
[31] http://www.euroshell-net.eu/Partners/Industry-partners/ISGA-IFA
[32] https://www.fsai.ie/uploadedFiles/About_Us/Industry_Fora/MSSC/CoP_Biotoxin_Monitoring.pdf
[33] http://www.marine.ie/Home/site-area/data-services/interactive-maps/weekly-hab-bulletin
[34] http://oar.marine.ie/
[35] http://www.conference.ie/Conferences/index.asp?Conference=451
[36] http://www.issha.org/Welcome-to-ISSHA/Conferences/ICHA-Conferences

National HAB and Biotoxin monitoring Programme History

There is a relatively short recorded Irish history of Harmful Algal Blooms with little or no documentation prior to the 1970s. In 1976, shellfish samples in coastal areas affected by HABs were collected and tested for Paralytic Shellfish Poisoning biotoxins using the rat bioassay (Parker *et al.* 1982). In the late 1970s, regular high biomass nuisance blooms of a dinoflagellate, called *Karenia mikimoitoi,* caused fish kills of farmed trout and salmon in the south and southwest (Parker *et al.* 1982). Monitoring of HABs, at the time was ad hoc and primarily driven by academic interests (Roden *et al.* 1980, Jenkinson and Connors 1980, Pybus 1980). In 1984, the Irish Biotoxin and Phytoplankton Monitoring Programme was established in response to the rapidly developing Irish shellfish industry (Jackson and Silke 1995). The initial programme involved field trips, made by the Department of Fisheries staff, to the southwest coast where shellfish production had grown substantially. Water samples were collected to determine phytoplankton species present and a rat bioassay was used to test shellfish flesh for biotoxins (Silke 2002). In the early 1990s, shellfish aquaculture activities expanded to the west and northwest coasts, and monitoring efforts increased (Silke 2002). By 1995, testing was carried out year round to capture toxic events in winter. A summary of methodological and legislative changes, e.g. a switch from rodent assays to chemical analytical biotoxin detection, in the monitoring programme since 1990 are captured in Figure 5 below. Further details can be found in the proceedings of past Shellfish Safety Workshops[37].

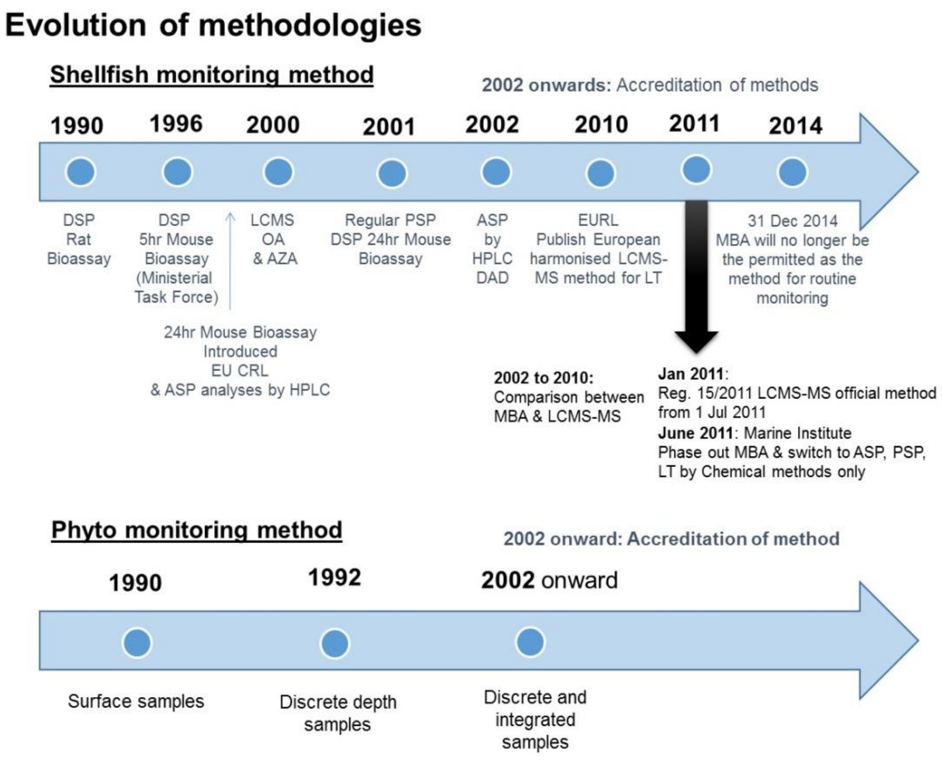


Figure 5. Ireland's National Monitoring Programme History – an evolution of methodological changes in testing shellfish and water samples from 1990 to present. Laboratory accreditation for the methods began in 2002.

Today, water and shellfish samples are collected through the Irish Shellfish Harvesting Monitoring Programme, and analysed by the EU designated National Reference Laboratory (NRL) for marine biotoxins and phytoplankton (Irish Marine Institute) to fulfil EU Hygiene Regulations 853/2004 and 854/2004 (Anon. 2004) and the test methods used to detect biotoxns as described in Regulation (EC) No 2074/2005.

[37] https://oar.marine.ie/

Metadata records for HABs[38] and Biotoxins[39] are available in the Irish Data Spatial Exchange website[40]. Samples are analysed through ISO Certified INAB approved chemistry (biotoxin) and biological (phytoplankton) laboratory methods. For complete details on the monitoring programme refer to the Irish Food Safety Authority[41] code of practice, at the time of writing this is in Version 7[42]. Relevant Irish legislation related to shellfish food safety and marine biotoxins includes SI 432/2009 - The European Communities (Food and Feed Hygiene) Regulations, 2009, The Food Safety Authority of Ireland Act, 1998 and the Sea-Fisheries and Maritime Jurisdiction Act 2006.

Research projects that led to the development of the bulletin and progress

A national development programme funded research project called BOHAB (Biological Oceanography of Harmful Algal Blooms) was initiated in 2003 in response to prolonged shellfish harvesting closures and demand from industry to determine causes of the initiation, progression and subsidence of HABs in Irish Bays with intensive aquaculture. The project developed the scientific conceptual models needed to understand the physical processes involved in transporting HABs into the Bays. The same year, a HABs national phytoplankton and biotoxin database was created (called HABs); results were transmitted to end-users online, by fax and/or by text (Short Message Service).

Between 2011 and 2013, the HAB bulletin was developed through the EC FP7 ASIMUTH project (Applied Simulations and Integrated Modelling for the Understanding of Toxic and Harmful Algal Blooms). In 2014, the FP7 MyOcean2 project supported the continued publication of the online HAB bulletin and the development of new products. The HAB bulletin continues to evolve thanks to the iterative process of the feedback loop from users/customers requesting improvements or addition of new data products of relevance described in the Introduction.

Recent activities in the H2020 AtlantOS project (2015 -2019) relate to promoting and sharing information (scripts etc.) with partners in Spain and Norway and providing information on “how-to” develop a HAB bulletin in other countries. End-users along the value chain have also been identified. AtlantOS is also following the EMODnet process to evaluate “Fitness for Use of Input Data” and “Fitness for Purpose of the Products”.

The Interreg PRIMROSE project (2017 - 2020) will enhance the existing bulletin production by building on the existing monitoring programmes carried out in partner regions to estimate harmful phytoplankton blooms, shellfish biotoxins and microbial contamination to comply with EU regulations. It will add value to these programmes by re-use of valuable data that is already being generated. This will aid the aquaculture sector by providing a look-ahead product that will help grow, innovate and generate jobs in the aquaculture sector. This sector relies heavily on sufficient early warning of harmful events, so that mitigation measures can be put in place. PRIMROSE will both develop a trans-national short to medium term risk forecast and will also look at the longer term assessment of climate impact and its impact on providing such harmful algal blooms and pathogens forecasting. The project will add new products to its content, assist with automation to save time in the preparatory steps before the bulletin is published and enhance the scientific support to the Irish NMP (National Monitoring Programme).

Within the JPI climate ERA4CS CoCliME project (2017 - 2020), the existing HAB bulletin process is being used as a basis for developing a climate service offering the aquaculture industry and other stakeholder’s

[38] http://www.isde.ie/#/189c7356-385e-405f-b5e4-50ee49b6e90f
[39] http://www.isde.ie/#/5f2a2f06-fd75-46ad-a30c-1c45b7261303
[40] http://www.isde.ie/
[41] https://www.fsai.ie/enforcement_audit/monitoring/shellfish.html
[42] https://www.fsai.ie/uploadedFiles/About_Us/Industry_Fora/MSSC/CoP_Biotoxin_Monitoring.pdf

insight into potential changes that may affect them on timescales from seasonal to decadal and longer if this need is driven by the users.

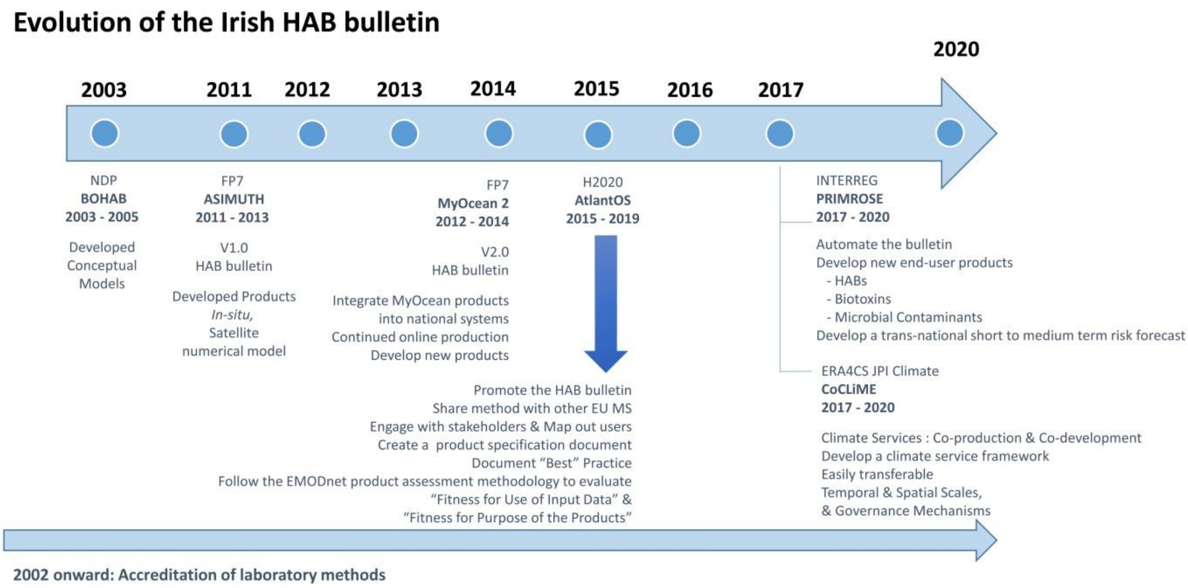


Figure 6. Evolution of the HAB bulletin, an iterative process.

4. *Best Practice Description*

An overview of the process for creating the weekly HAB bulletin is shown in Figure 7. The sub-processes in this diagram are expanded in detail in the sections below.

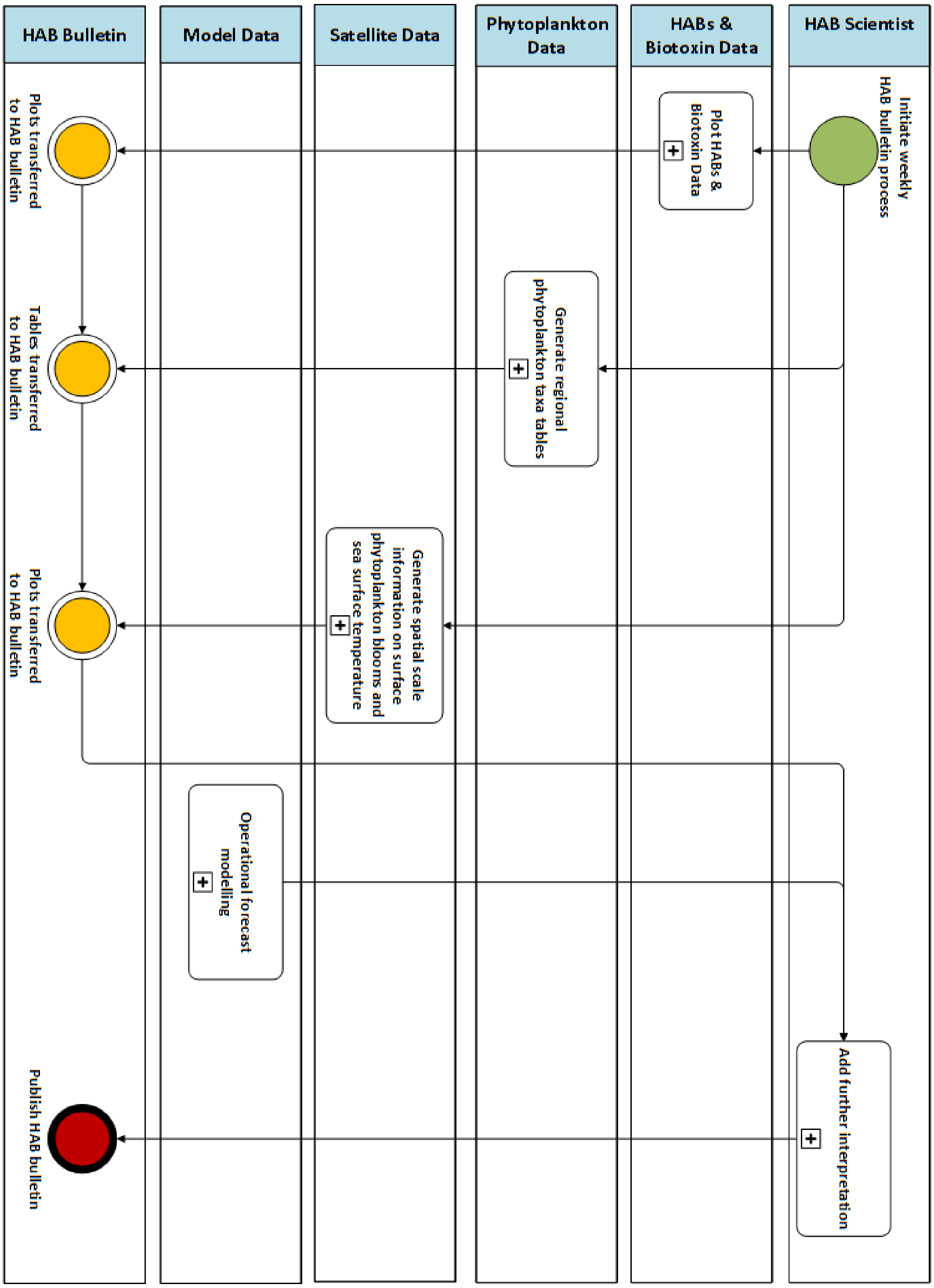


Figure 7. An overview of the complete process to create a weekly HAB bulletin. This diagram, and those that follow, use the Business Process Notation Model, or BPMN, for their semiotics.

Steps for implementation

1. Process 1-01: In-situ HAB & biotoxin products

Purpose: To provide a synopsis of the current conditions of HAB & biotoxins in spatio-temporal plots, summarised in
Figure 8.

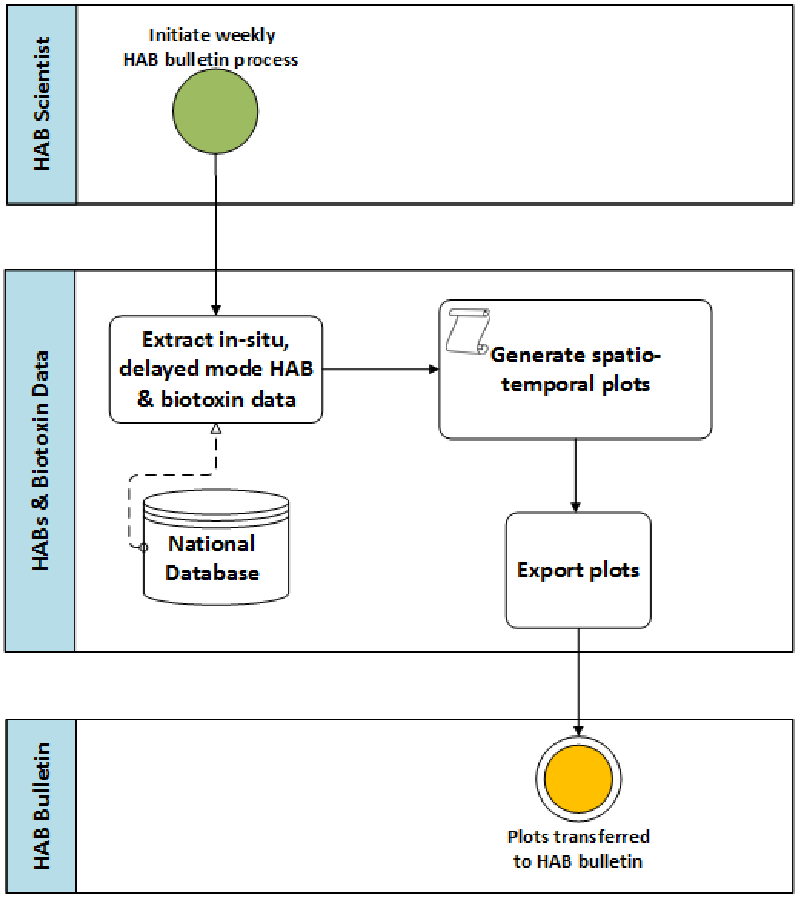


Figure 8. Detailed process flow for the In-situ HAB and biotoxin products for inclusion in the final HAB bulletin.

Step	Major Activity	References, Forms, and Details
1.	Extract *In-situ*, delayed mode HAB and biotoxin data from the national database.	Laboratory (phytoplankton and biotoxin chemistry) analytical data results are deposited in a HAB (Harmful Algal Bloom) SQL Server database application at the Marine Institute.
2.	Generate spatio-temporal plots (maps; X-Y scatter plots).	Scripts written in the R Statistical Programming Language (R Development Core Team, 2008) are used to produce the HAB and biotoxin data products for the weekly HAB bulletin[43]. Prior to running the script the operator must fill in end date (YYYY-MM-DD format)

[43] https://github.com/IrishMarineInstitute/bulletin-scripts/blob/master/habs_plots_2016_05_16.r

		end_date <- '2016-08-14' (the end_date is the last day for which you want the report to run) You should be able to simply change the end_date at the start of the script (and change the working directory, if you want) and run it.
3.	Export the plots	The R script automatically saves and exports the output files in PNG format (*.png) to a Marine Institute server. Script runs and Data Product Components produced as PNG files saved on the MI server. A description and example plot of each data product component are presented in Annex 1.
4	Transfer the plots to the HAB bulletin.	The User manually copies and pastes the plots they think are useful into the weekly HAB bulletin

2. *Process 1-02: Phytoplankton data products*

Purpose: To create a table reporting the top five most abundant phytoplankton taxa for the previous week in the five coastal regions (east, south, southwest, west, north), summarised in Figure 9.

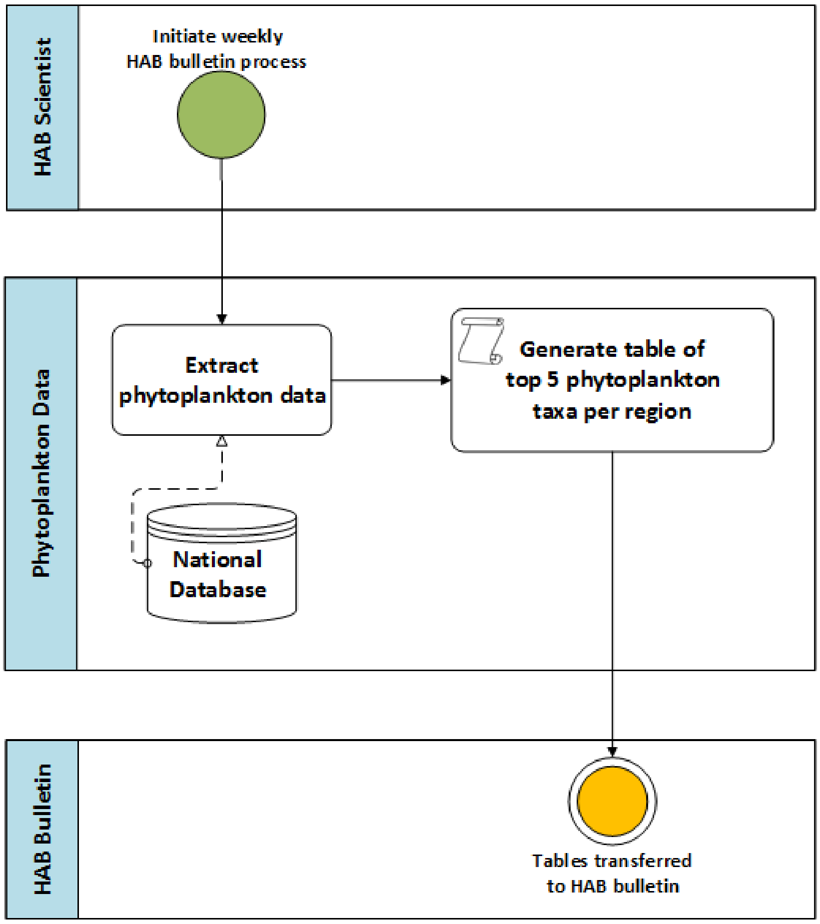


Figure 9. Detailed process flow for the creation of phytoplankton data products for inclusion in the final HAB bulletin.

Step	Major Activity	References, Forms, and Details
1.	Extract *In-situ*, delayed mode phytoplankton data (taxa and cell densities) from the national database.	HAB (Harmful Algal Bloom) SQL Server database application at the Marine Institute. SQL Server Reporting Services “HABS Top 5”
2.	Generate a table of the top five phytoplankton taxa list for each geographical region in a selected week i.e. a table with a top five weekly phytoplankton taxa list with the maximum cell densities recorded in each region.	A quick and simple report called the “HABS Top5” is generated automatically through a restricted URL address the User has access to for the weekly HAB bulletin. The Top 5 report takes the following parameters: • StartDate - The start date (first day) of the sample data • EndDate - The last day of the sample data • count - The number of results to return. Defaulted to 5 (for Top 5) but can return more or less data e.g. Top 10, Top 3 The count numbers for each species are rounded up/down to the nearest 1000 cells/Litre. An example table of this data product component is presented in Annex 2.
3	Transfer Table to the HAB bulletin.	The User manually copies and pastes the resulting table into the weekly HAB bulletin.

3. *Process 1-03: Satellite*

Purpose: To provide a synopsis of the current sea surface conditions of ocean temperature and colour in spatial maps, summarised in
Figure 10.

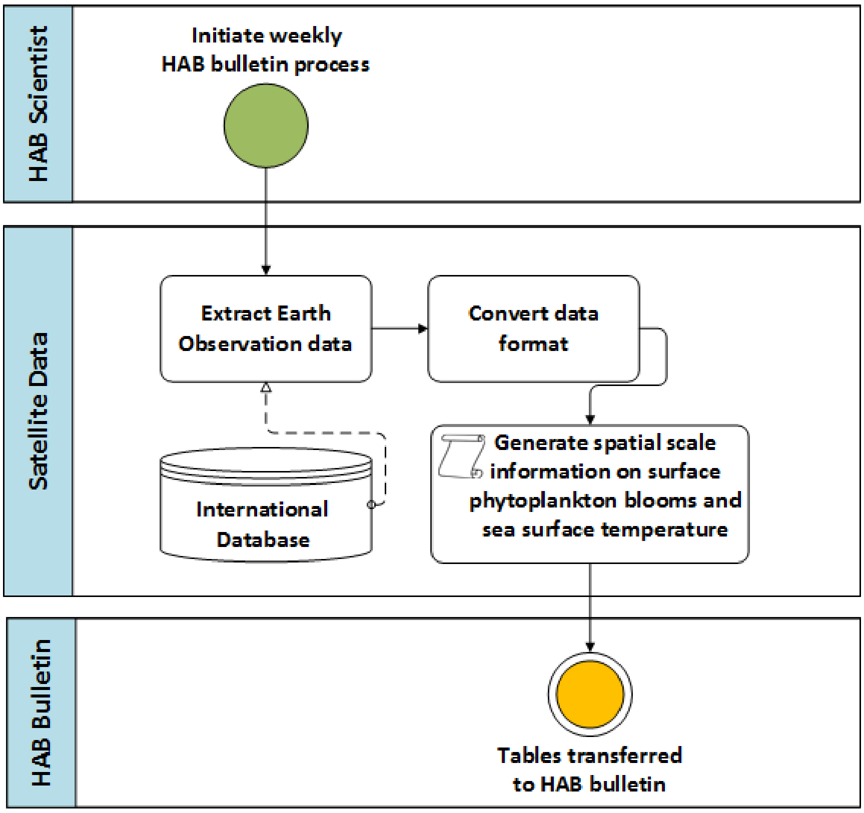


Figure 10. Detailed process flow for satellite data products for inclusion in the final HAB bulletin.

Step	Major Activity	References, Forms, and Details
1.	Extract EO data from international databases.	*Surface Chl a* The Level 4 sea surface Chl a data product, developed by IFREMER/ DYNECO and CERSAT in Brest, is extracted from the IFREMER FTP site. **IFREMER URL:** *ftp://ftp.ifremer.fr/ifremer/cersat/products/gridded/ocean-color/atlantic/EUR-L4-CHL-ATL-v01* **Data Product:** EUR-L4-CHL-ATL-v01 **Data format:** Netcdf *Sea Surface Temperature* ODYSSEA L4 SST observation data is extracted from Copernicus Marine Environmental Monitoring Service (DG Growth) Marine Core Service (CMEMS MCS) **COPERNICUS URL:** **Data product:** SST_NWS_SST_L4_NRT_OBSERVATIONS_010_003 **Data format:** Netcdf
2.	Convert data into readable format to create spatial maps.	Matlab is used to convert the L4 data product Netcdf files to *.grd files.

		All data processing is performed as an automatic task using the commercial software package, Matlab.
2.	Generate spatial scale information on surface phytoplankton blooms (Chl*a* measurements) and sea surface temperature (SST).	Matlab is used to calculate chlorophyll anomalies from the 60-day median value calculated using data between current date minus 74 and current date minus 14. This anomaly data is rendered as .png files. Weekly mean anomalies are calculated and saved as *.grd files[44]. Scripts written in the R Statistical Programming Language (R Development Core Team, 2008) are used to produce SST and chlorophyll *a* data products for the weekly HAB bulletin[45]. Prior to running the script the operator must fill in end date (YYYY-MM-DD format) e.g. end_date <- '2017-08-17' (the end_date is the last day for which you want the report to run) The Use simply changes the end_date at the start of the script (and change the working directory, if necessary) before running the script Result: most up-to-date daily Satellite maps present large spatial scale information on surface phytoplankton blooms (Chl a measurements) and sea surface temperature (SST). Subcomponents A. Chlorophyll *a* levels and distribution B. Chlorophyll *a* anomaly levels and distribution C. Sea Surface Temperature levels and distributions Data Product example plot is presented in Annex 3.
3.	Transfer Table to the HAB bulletin.	The User manually copies and pastes the resulting plot into the weekly HAB bulletin.

4. *Process 1-04 Calculate chlorophyll and SST anomalies*

Purpose: To provide an overview of the current weekly conditions in relation to historical chlorophyll and SST conditions detailed in
Figure 11.

[44] https://github.com/IrishMarineInstitute/bulletin-scripts/blob/master/asimuth_weekly_chl_anomaly.m
[45] https://github.com/IrishMarineInstitute/bulletin-scripts/blob/master/gridmaps-Weatherbuoy-positions-SSTmap_ColorBrewer-Seq-YlGr%2B7RdYlBu.r

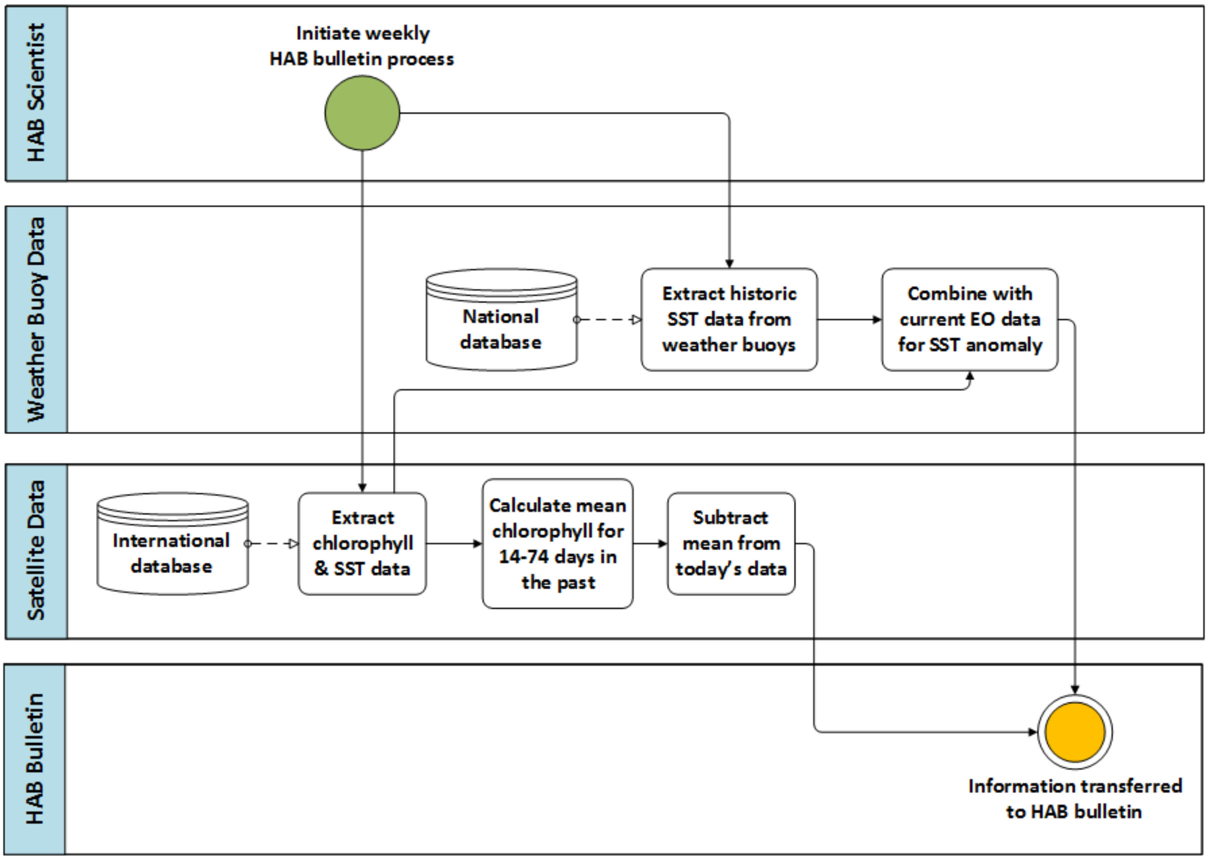


Figure 11. A detailed view of the chlorophyll and SST anomaly product process for inclusion in the final HAB bulletin.

Step	Major Activity	References, Forms, and Details
1.	Extract EO data from international databases.	*See process 1-03*
2.	Establish chlorophyll baseline	Retrieve EO data for between 14 and 74 days ago. Obtain the median value for each pixel. R scripts (var_median_apv_v0, habanom_aps_v0) are used to automate this step.
3.	Generate the chlorophyll anomaly	Subtract the baseline from today's satellite data
4.	Generate long-term SST anomaly	*See process 1-05*

The chlorophyll anomaly method was developed by Michelle Tomlinson and Richard Stumpf, NOAA, USA.

5. *Process 1-05: In-situ weather buoys*

Purpose: To create a ten year SST anomaly for the week in question detailed in Figure 11.

Step	Major Activity	References, Forms, and Details
1.	Extract *In-situ*, delayed mode sea surface temperature data from the MI Databuoy database.	*SST buoy anomalies* Matlab scripts are run daily to calculate the SST anomaly for each weather buoy off the Irish Atlantic coast. The anomaly is based on the long term weekly average so each measured SST value has the appropriate weekly average value subtracted from it and the result is displayed on a plot with red bars indicating points above the average and blue bars indicating below average. A single weekly anomaly value is also displayed on the plot as text at end of each individual week. *Sea Surface Temperature o*bservation data is one of the parameters collected by the Irish weather buoy network and is stored in a SQL Server database at the Marine Institute. **URL:** www.marine.ie/home/publicationsdata/data/buoys/Observations.htm **Also available through Copernicus (CMEMS)** **URL:** www.marine.copernicus.eu **Data product:** INSITU-IBI-NRT-OBSERVATIONS-013-033 **Data format:** netcdf **Script:** asimuth_buoy_sst_anomaly.m The Matlab script automatically saves and exports the output files in JPEG format (*.jpg) to a Marine Institute server. Script runs and Data Product Components are produced as JPEG files saved on the MI server. Data Product example plot is presented in Annex 4.

6. *Process 1-06: Modelled data products*

Purpose: To provide particle tracking imagery and 3-day predictive hydrodynamics for bays of interest, detailed in
Figure 12.

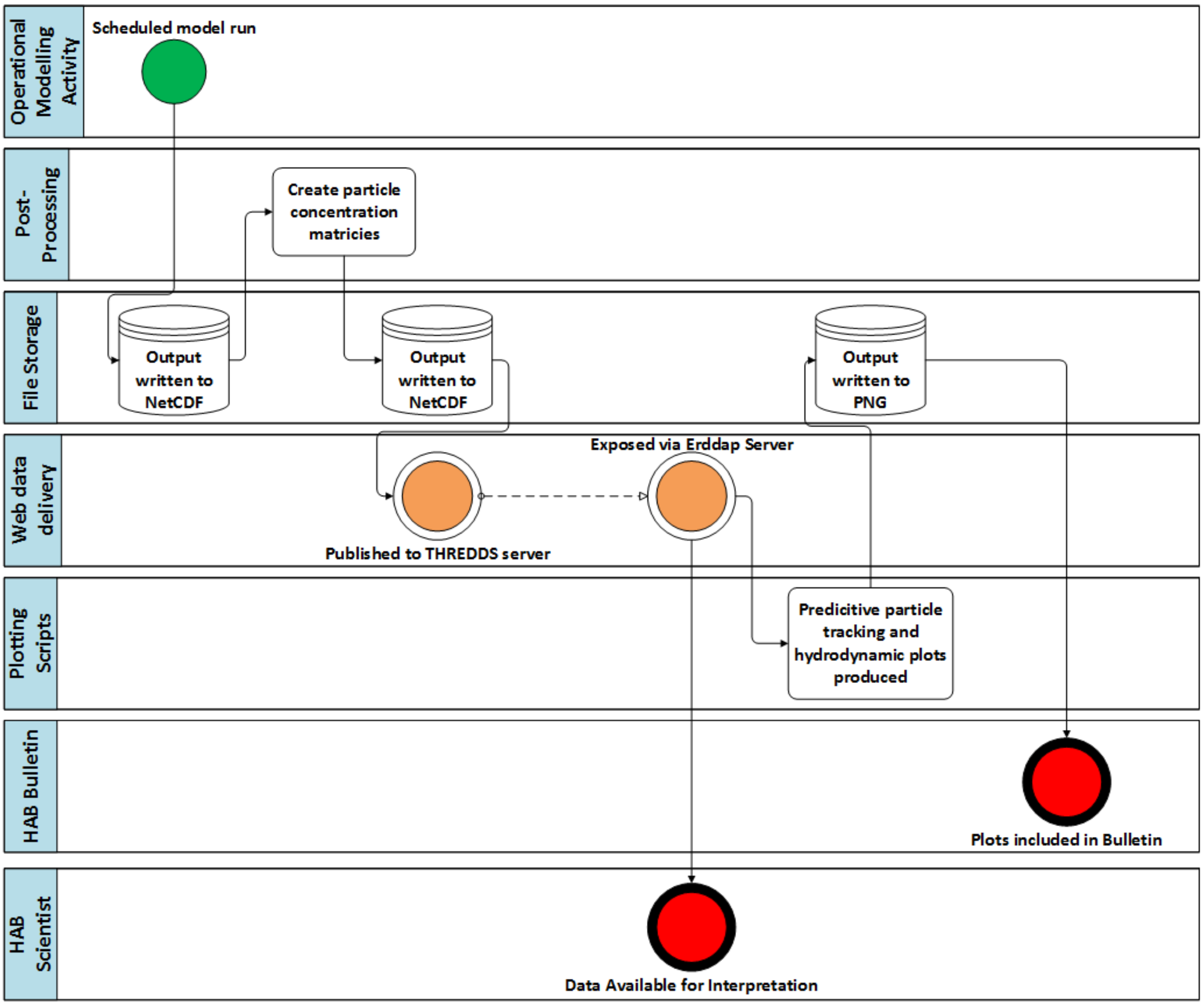


Figure 12. A detailed view of the modelled data product process, the outputs of which are used both for direct inclusion in the HAB bulletin and for further expert interpretation by HAB scientists.

Step	Major Activity	References, Forms, and Details
1.	Nightly run of operational forecast models	Hydrodynamic forecast from the Regional Ocean Modelling System (ROMS) model for three days in Irish coastal water are created at various scales: • 1 x regional model run • 2 x downscale model runs (Bantry Bay, Connemara) The downscale models also incorporate online particle tracking with virtual particles released at pre-defined transects at the start of each model run.

		The particle tracking data is written to NetCDF files for post-processing.
2.	Post-processing of particle tracking data from downscale model runs	Matlab is used to read model particle tracking data and create particle concentration matrices based on residency of particles per model cell. Data is then written to netcdf file and exported to the MI THREDDs server
3.	Disseminate data via ERDDAP	The "Bantry Bay model particle track analysis" dataset on https://erddap.marine.ie/ provides access to the HABs report creator Data Product example plot is presented in Annex 5.
4.	Produce plots for the bulletin	Daily automated run Matlab scripts produce hydrodynamic nowcast/forecast model output image files (*.png) for Bantry Bay[46]. The files represent model ouputs at a horizontal resolution 200 – 250 m with 20 vertical levels. The images used in the bulletin show the latest 3-day volumetric flux forecast for vertical transects at the mouth of Bantry Bay and mid-bay. Results are plotted graphically on a map of the bay. Predictions (3-day) of temperature, salinity and density at the mouth of Bantry Bay are also produced. Data for model forcing and initial conditions comes from several sources including Copernicus marine services. Plots produced include: • Predicted water movement in the vicinity of Bantry Bay, SW Ireland. • Physical water properties at the mouth of Bantry Bay, SW Ireland. • Predicted water movement in the vicinity of Killary Harbour, W Ireland. • Physical water properties at the mouth of Killary Harbour, W Ireland. • Predicted water movement in the vicinity of Aughrus Point, W Ireland. • Physical water properties at the mouth of Aughrus Point, W Ireland

[46] https://github.com/IrishMarineInstitute/bulletin-scripts/blob/master/asimuth_bantry_bay_plots.m

7. *Process 1-07: Bulletin Expert opinion Prediction based on expert opinion*

Purpose: To produce the bulletin

Step	Major Activity	References, Forms, and Details
1.		A text prediction and rational, based on interpretation of all available data by local scientists, is presented. The rationale is based on available scientific data, potential driving factors and experience.

8. *Process 1-08: Publish the HAB bulletin*

Step	Major Activity	References, Forms, and Details
1.		*Upload bulletin to webpage*

5. Data Required

- Laboratory analytical results
  - Phytoplankton biomass and diversity
  - Biotoxins / Phycotoxins
- *In-situ*, delayed mode data (fixed points)
  - Phytoplankton biomass and diversity
  - Sea Surface Temperature
- Earth Observation data
  - Sea surface temperature
  - Phytoplankton biomass and diversity
- Numerical model outputs
  - Subsurface currents
  - Surface currents
  - Particle tracking model outputs

6. Tools, Models and Software required

Software Package: R
Minimum Version: Version 3.2.2 (2015-08-14)
R libraries required: RODBC
mapplots
sp
raster
rgdal
ncdf
shapefiles
RColorBrewer
Platform: x86_64-w64-mingw32/x64 (64-bit)
Software Package: Matlab
Minimum Version: Revision R2013a
Software Package: ROMS model
Software Package: Ichthyop particle transport model

7. International Standards used

Laboratory measurements are made to the ISO17025 standard. International laboratory biological intercomparisons operate according to the ISO17043 and to the ISO 13528 Statistical methods for use in proficiency testing. Data Management follows IODE Data Management Quality Framework practices.

8. Quality Control

All laboratory standard operating procedures are stored within a Paradigm 3 document management system which is implemented as part of the ISO17025 compliance listed above. Data Management processes, including model data quality control, are documented to ISO9001:2015 standard for IODE Data Management Quality Framework compliance. Laboratory methods at the Marine Institute are accredited by the *Irish National Accreditation Board* (INAB) to ISO/IEC 17025:2005. The Marine Institute co-ordinates and manages the International Phytoplankton Intercomparison (*IPI*) to provide enumeration and identification quality assurance in marine phytoplankton (previously under the umbrella of *BEQUALM*). Intercomparison exercises are carried out annually. This is a Marine Institute and UNESCO- IOC cooperation and operates according to the ISO17043 Conformity assessment-General requirements for proficiency testing and ISO13528 Statistical methods for use in proficiency testing by interlaboratory comparisons. The initiative is currently applying for 2017 accreditation as a proficiency testing scheme under ISO17043 to the INAB.

Reporting Format
The HAB bulletin is delivered to end users as a PDF document.

9. Conclusions

There is a consistent use of the HAB bulletin product. In 2017, 1,723 unique visitors made 2,855 views on the bulletin web pages. Page views per day vary seasonally and with different impending biotoxin risk, up to a peak of 77 views recorded on a single day in late February 2017.

The HAB bulletin continues to evolve thanks to the iterative process of the feedback loop from users/customers requesting improvements or addition of new data products of relevance described in the Introduction. As part of the ASIMUTH project, users of the HAB bulletin were surveyed to get initial requirements and feedback (Maguire *et al.* 2013, Maguire *et al.* 2016).

Maguire et al. 2013 stated:

> "Based on the results of the survey circulated, to gather feedback from end-users (23 fish farmers) of the bulletin, 80% of the stakeholders found the bulletin useful and many used it to make decisions related to their farms. The main use of the HAB bulletin information related to harvest planning and the best time to place shellfish on the market. Ninety three percent of the survey respondents felt the HAB bulletin contained enough information to make it a useful tool. The data information products in the bulletin was useful.
>
> When considering the minimum timeframe for a short-term forecast to be of use to them, the majority (88%) of respondents felt that between three days and one week was sufficient. This timeframe allows aquaculturists to plan their harvesting in such a way that avoids mortalities and financial losses. When asked to rate the ASIMUTH HAB forecasting system overall, 67% of respondents felt it was "good" or 'very good' with the remainder (33%) rating it 'excellent'. 90% of questionnaire respondents would find a long term or seasonal forecast beneficial for a number of reasons: Planning; Marketing; Harvesting; Production plans; Showing trends; Identifying triggers. However, they also had concerns with the accuracy of such predictions. One respondent stated that if a more long-term forecast was to be developed 'these predictions should be accompanied by the probability of their accuracy.'
>
> The high levels of positive responses from the questionnaire suggested that the ASIMUTH bulletin is a tool which aquaculturists and industry found beneficial in planning and decision making."

This goes a long way to justify the continued development of the bulletin, despite challenges in the technical implementation of the HAB bulletin including the need to integrate data from a wide variety of sources. This is often an issue in data intensive projects and the use of a data server, such as Erddap, which brokers the different data sources into a suite of common data formats is one step can address this. Generating the HAB bulletin document is another challenge, one which currently requires the use of template documents in PowerPoint and the insertion of images that are outputs from various sources. While several steps in the process to create the HAB Bulletin have been automated this automation has not been orchestrated and still requires manual intervention along the way. These latter two points could be addressed in a system based around a Jupyter notebook. Finally, there is the issue of the manual interpretation of results. Ideally a machine learning approach could be taken to address this and automatically interpreting the results for the various bays. However, close collaboration and monitoring by local experts will still be required.

The shellfish and wider aquaculture industry have endorsed the benefits of forecasting reports for the sustainable use of marine fish and shellfish resources (Maguire *et al.* 2016). The dissemination of periodic bulletins to end users from monitoring agencies and the aquaculture sector was shown to be an effective means to publish information direct to those stakeholders best positioned to avail of these advisory products. The requirements identified by these stakeholders have been taken into account for the restructuring of enhancement of the bulletins under the forthcoming PRIMROSE project. This will further demonstrate the benefits of a sustained weekly issue of forecasting bulletins, particularly in countries when project funds dry up. The success of how Ireland managed to continue production of the HAB bulletin as a national commitment is testament to this.

This document was compiled to share the methodology used in Ireland with the community and to encourage future improvement and knowledge transfer between international groups who work on developing risk assessment aids related to human health and environmental monitoring.

10. Acknowledgements

The authors would like to thank multiple parties who have played a part in developing and/or improving the current HAB bulletin. Special thanks to Donald Anderson, Alan Berry, Tara Chamberlain, Marcel Cure, Tomasz Dabrowski, Keith Davidson, Conor Duffy, Declan Geoghegan, Paula Hynes, Dan Lynch, Kieran Lyons, Julie Maguire, Marcus Mateus, Yvonne McFadden, Georgina McDermott, Dennis McGillycuddy, Mark Mellett, Tearsa Moita, Helena Mouriño, Glenn Nolan, Shane O'Boyle, Gerard O'Flynn, Eleanor O'Rourke, Dominic O'Toole, Nadia Pinardi, Robin Raine, Beatriz Regeura, Chris Reynolds, Manuel Ruiz Villarreal, Rafael Salas, Damian Smyth, Marc Sourisseau, Richard Stumpf, Michelle Tomlinson and Robert Wilkes.

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Annex 1 Data Product Component Description and Example: HAB & Biotoxin Data product components PNG file contents

No.	File name & Type	Description
1	HistoricPlots.png	Historic trends of regional shellfish harvesting closures for a selected week. A ten-year account of regional aquaculture shellfish harvesting site closures when biotoxins exceeded the EC Regulatory levels in shellfish are presented for a selected week in the year. Biotoxins include Pectenotoxin (PTX)-group toxins and biotoxins that cause the human illnesses Paralytic Shellfish Poisoning (PSP), Diarrheic Shellfish Poisoning (DSP), Azaspiracid Shellfish Poisoning (AZP) and Amnesic Shellfish Poisoning (ASP) if contaminated shellfish are consumed. Presented as regional tabulated results overlaid on a map of the study area. Each table displays the number of sites closed and number of sites tested (sites toxic/sites measured) for the current week. This is displayed for each biotoxin type and for each year over the last ten years. A site closure occurs when biotoxins in shellfish exceed EC Regulatory levels.
2	ASP_donut.png	Regional overview of toxic and/or nontoxic sites that have Domoic acid above the EC Regulatory Limit of 20 µg/g in shellfish; displayed as doughnut plots. This biotoxin can cause Amnesic Shellfish Poisoning in humans if contaminated shellfish are consumed. The plots include the number of sites/farms sampled in each region and the percentage of sites in each region that were found to be toxic in the week number displayed.
3	AZP_donut.png	Regional overview of toxic and/or nontoxic sites that have Azaspiracid (AZA)-group biotoxins above the EC Regulatory level of 0.16 µg/g in shellfish; displayed as doughnut plots. These biotoxins can cause Azaspiracid Shellfish Poisoning in humans if contaminated shellfish are consumed. The plots include the number of sites/farms sampled in each region and the percentage of sites in each region that were found to be toxic in the week number displayed.
4	DSP_donut.png	Regional overview of toxic and/or nontoxic sites that have Okadaic acid and analogues (in Ireland, this refers to Okadaic Acid, DTX-1 DTX-2, esters) biotoxins above the EC Regulatory level of 0.16 µg/g in shellfish; displayed as doughnut plots. These biotoxins can cause Diarrheic Shellfish Poisoning in humans if contaminated shellfish are consumed. The plots include the number of sites/farms sampled in each region and the percentage of sites in each region that were found to be toxic in the week number displayed.
5	PSP_donut.png	Regional overview of toxic and/or nontoxic sites that have Saxitoxin above the EC Regulatory level of 800 µg/Kg in shellfish; displayed as doughnut plots. These biotoxins can cause Paralytic Shellfish Poisoning in humans if contaminated

		shellfish are consumed The plots include the number of sites/farms sampled in each region and the percentage of sites in each region that were found to be toxic in the week number displayed.
6	PTX_donut.png	Regional overview of toxic and/or nontoxic sites that have Pectenotoxin (PTX)-group biotoxins above the EC Regulatory level of 0.16 µg/g in shellfish; displayed as doughnut plots. The plots include the number of sites/farms sampled in each region and the percentage of sites in each region that were found to be toxic in the week number displayed related to DSP events.
7	*Azadinium*-like cells.png	National distribution maps show cell densities of a potentially toxic dinoflagellate from the genus *Azadinium* over a 3 week period. Three maps are produced - one for each week selected by the User. Some species from the genus *Azadinium* are known to produce the biotoxin Azaspiracid related to AZP events.
8	*Pseudo-nitzschia seriata* complex.png	National distribution maps show cell densities of a potentially a potentially toxic diatom from a size group called "*Pseudo-nitzschia seriata" over* a 3 week period. Three maps are produced - one for each week selected by the User. Some species from this *Pseudo-nitzschia* group are known to produce the biotoxin Domoic Acid related to ASP events.
9	*Pseudo-nitzschia delicatissima* complex.png	National distribution maps show cell densities of a potentially a potentially toxic diatom from a size group called "*Pseudo-nitzschia delicatissima" over* a 3 week period. Three maps are produced - one for each week selected by the User. Some species from this *Pseudo-nitzschia* group are known to produce the biotoxin Domoic Acid related to ASP events.
10	All *Pseudo-nitzschia* spp..png	National distribution maps show cell densities of a potentially a potentially toxic diatom from the genus *Pseudo-nitzschia* over a 3 week period. Three maps are produced - one for each week selected by the User. Some species from the genus *Pseudo-nitzschia* are known to produce the biotoxin Domoic Acid related to ASP events.
11	*Alexandrium* spp..png	National distribution maps show cell densities of a potentially toxic dinoflagellate from the genus *Alexandrium* over a 3 week period. Three maps are produced - one for each week selected by the User. Some species from the genus *Alexandrium* are known to produce Saxitoxin related to PSP events.
12	*Karenia mikimotoi*.png	National distribution maps show cell densities of a potentially nuisance dinoflagellate, *Karenia mikimotoi*, over a 3 week period. Three maps are produced - one for each week selected by the User. Blooms of *Karenia mikimotoi* discolour the water. Cells release a toxic irritant that damages the gills of shellfish,

		fish and invertebrates. Suffocation of marine life can arise when the bloom subsides and anoxic conditions occur due to an increase of bacterial activity.
13	All *Dinophysis* spp..png	National distribution maps show cell densities of a potentially toxic dinoflagellate from the genus *Dinophysis* over a 3 week period. Three maps are produced - one for each week selected by the User. Some species from the genus *Dinophysis* are known to produce the biotoxins Okadaic acid and its analogues related to DSP events.
14	*Dinophysis acuta*.png	National distribution maps show cell densities of a potentially toxic dinoflagellate, *Dinophysis acuta,* over a 3 week period. Three maps are produced - one for each week selected by the User. *Dinophysis acuta* are known to produce the biotoxins related to DSP events.
15	*Dinophysis acuminata*.png	National distribution maps show cell densities of a potentially toxic dinoflagellate, *Dinophysis acuminata,* over a 3 week period. Three maps are produced - one for each week selected by the User. *Dinophysis acuminata* are known to produce the biotoxins related to DSP events.
16	ASP.png	National distribution maps show Domoic acid levels in shellfish. Three maps are produced - one for each week selected by the User.
17	AZP.png	National distribution maps show Azaspiracid levels in shellfish. Three maps are produced - one for each week selected by the User.
18	DSP.png	National distribution maps show Okadaic acid and analogues levels in shellfish. Three maps are produced - one for each week selected by the User.
19	PSP.png	National distribution maps show Saxitoxin levels in shellfish. Three maps are produced - one for each week selected by the User.
20	PTX.png	National distribution maps show Pectenotoxin levels in shellfish. Three maps are produced - one for each week selected by the User.
21	plot1.png	Biotoxins levels plotted weekly from week 1 to the week selected by the User. These temporal plots show upward and downward trends in the national dataset of biotoxins related to AZP, DSP, PTX, ASP and PSP events.
22	plot2.png	Targeted phytoplankton cell counts are plotted weekly from week 1 to the week selected by the User. The temporal plots show upward and downward trends in the national dataset for

the following taxa, *Dinophysis acuminata, Karenia mikimotoi*, *Pseudo-nitzschia delicatissima* complex (< 3 µm size group of the genus *Pseudo-nitzschia*), *Dinophysis acuta, Alexandrium* spp., *Pseudo-nitzschia seriata* complex (> 3 µm size group of the genus *Pseudo-nitzschia*), All *Dinophysis* spp., All *Pseudo-nitzschia* spp., *Azadinium*-like cells

HAB & Biotoxin data product component examples.

HAB and Biotoxin results are presented in the temporal and spatial maps, plots and tables below. This provides the User with information on the current state of toxic and/or nontoxic sites for each biotoxins and the cell concentrations of harmful/toxic phytoplankton species in each region.

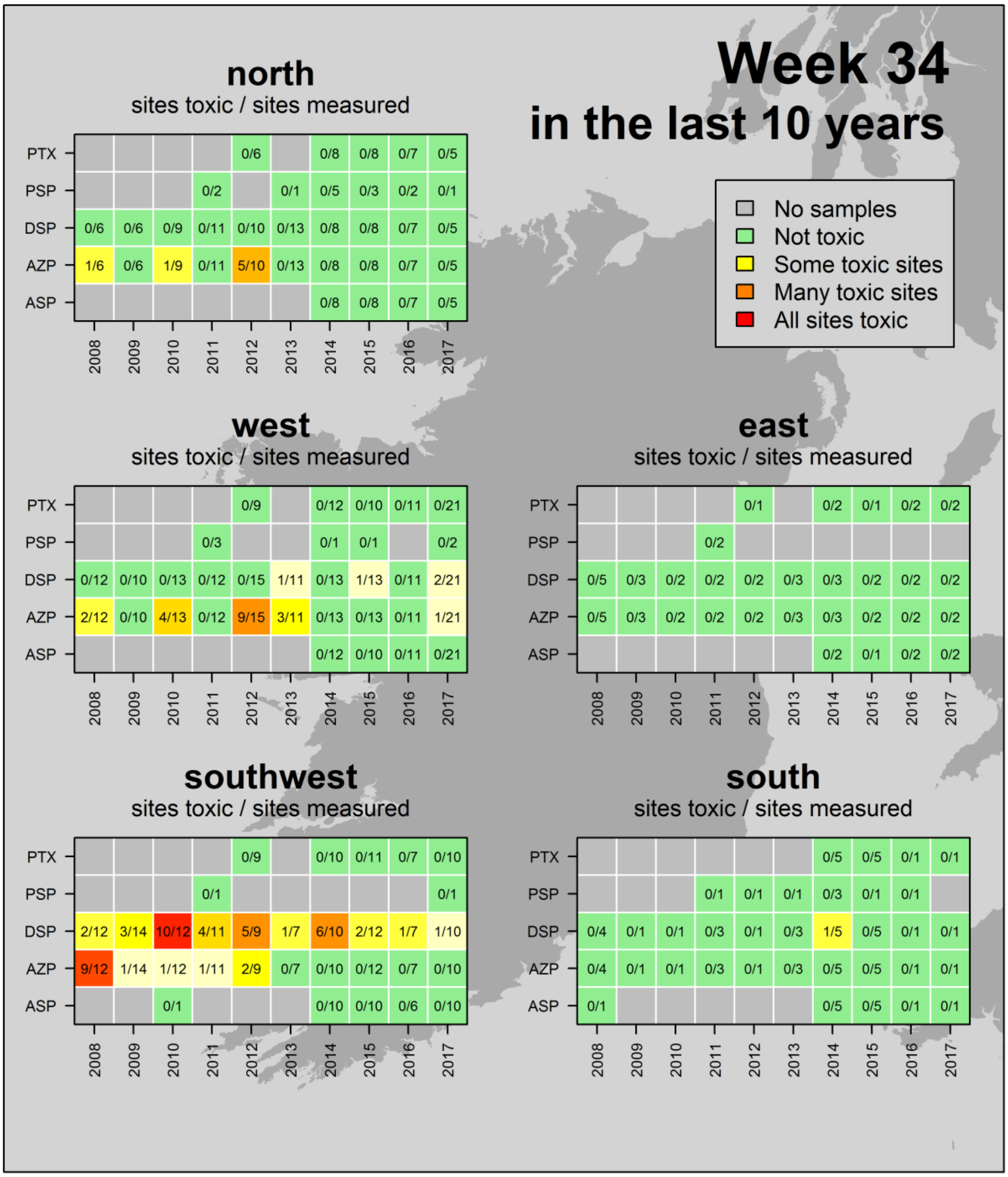


Figure 13. Ireland HISTORIC TRENDS; What happened this week over the past ten years? 2003-2012 Harvesting closures (biotoxins above regulatory levels).

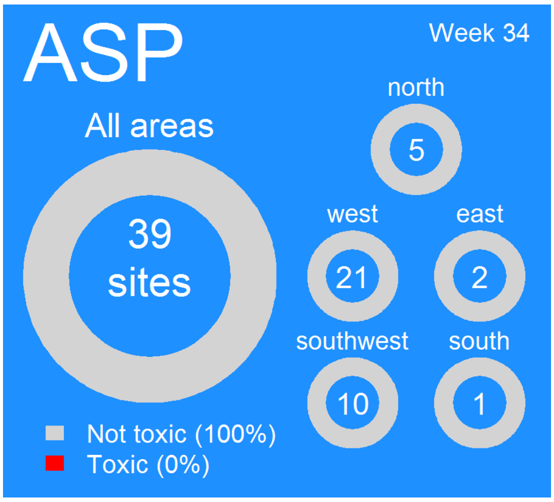


Figure 14. Weekly percentage of sites, nationally and regionally, that have/have not domoic acid biotoxin levels in shellfish above the EC Regulatory level. Plots show the number of sites/farms sampled.

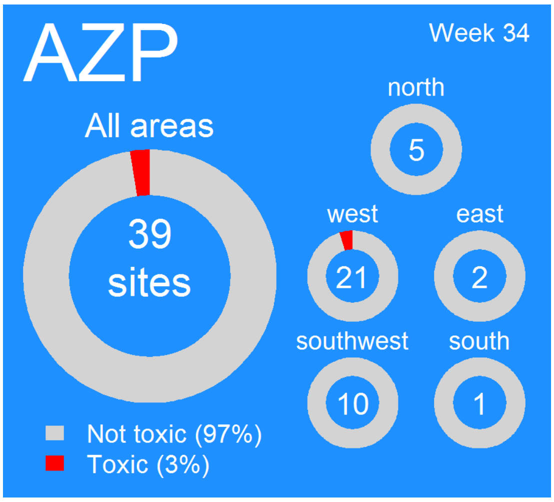


Figure 15. Weekly percentage of sites, nationally and regionally, that have/have not azaspiracid biotoxin levels in shellfish above the EC Regulatory level. Plots show the number of sites/farms sampled.

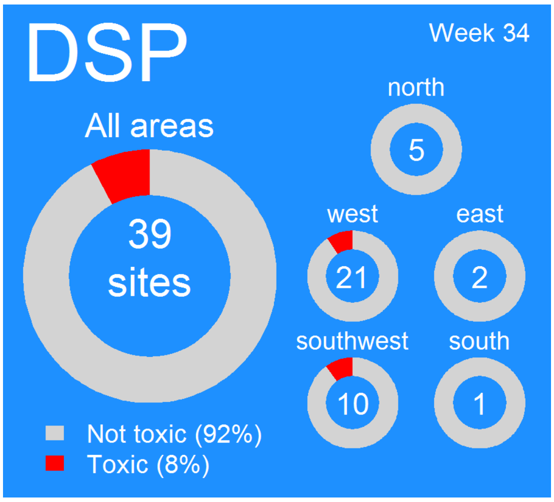


Figure 16. Weekly percentage of sites, nationally and regionally, that have/have not OA and equivalent biotoxin levels in shellfish above the EC Regulatory level. Plots show the number of sites/farms sampled.

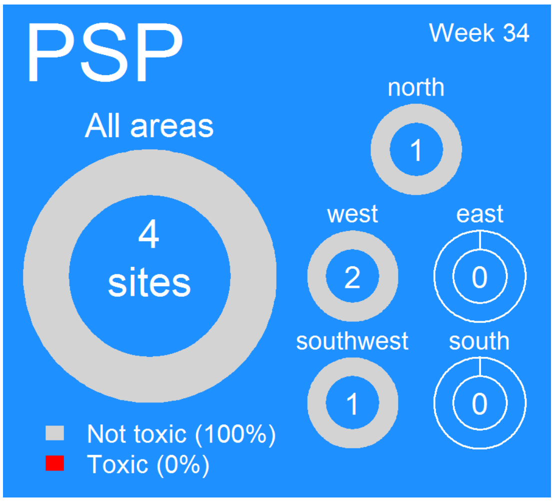


Figure 17. Weekly percentage of sites, nationally and regionally, that have/have not saxitoxin levels in shellfish above the EC Regulatory level. Plots show the number of sites/farms sampled.

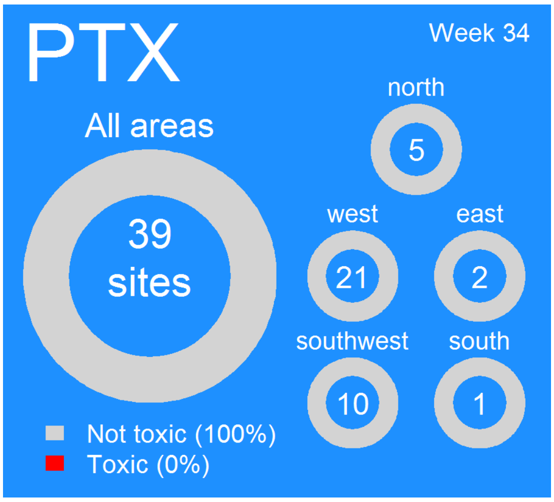


Figure 18. Weekly percentage of sites, nationally and regionally, that have/have not pectenotoxin levels in shellfish above the EC Regulatory level. Plots show the number of sites/farms sampled.

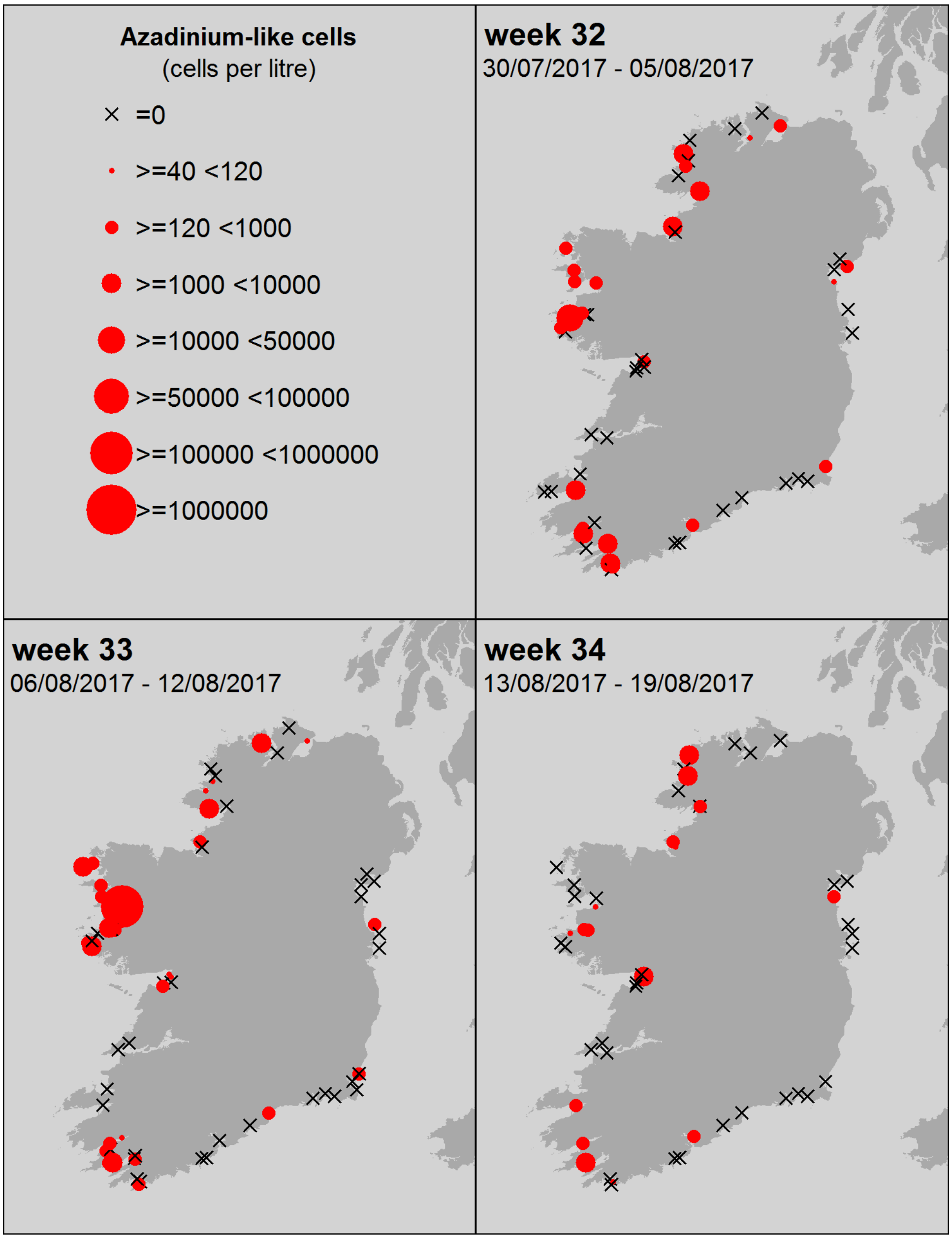


Figure 19. Distribution maps show Azadinium-like cell densities at sites/farms in Irish waters over a three week period. Cell densities are plotted as pre-set symbol sizes, colour coded to represent a category of values where x = not detected and red = cell densities. The red circles are further separated into seven categories that denote different cell density ranges.

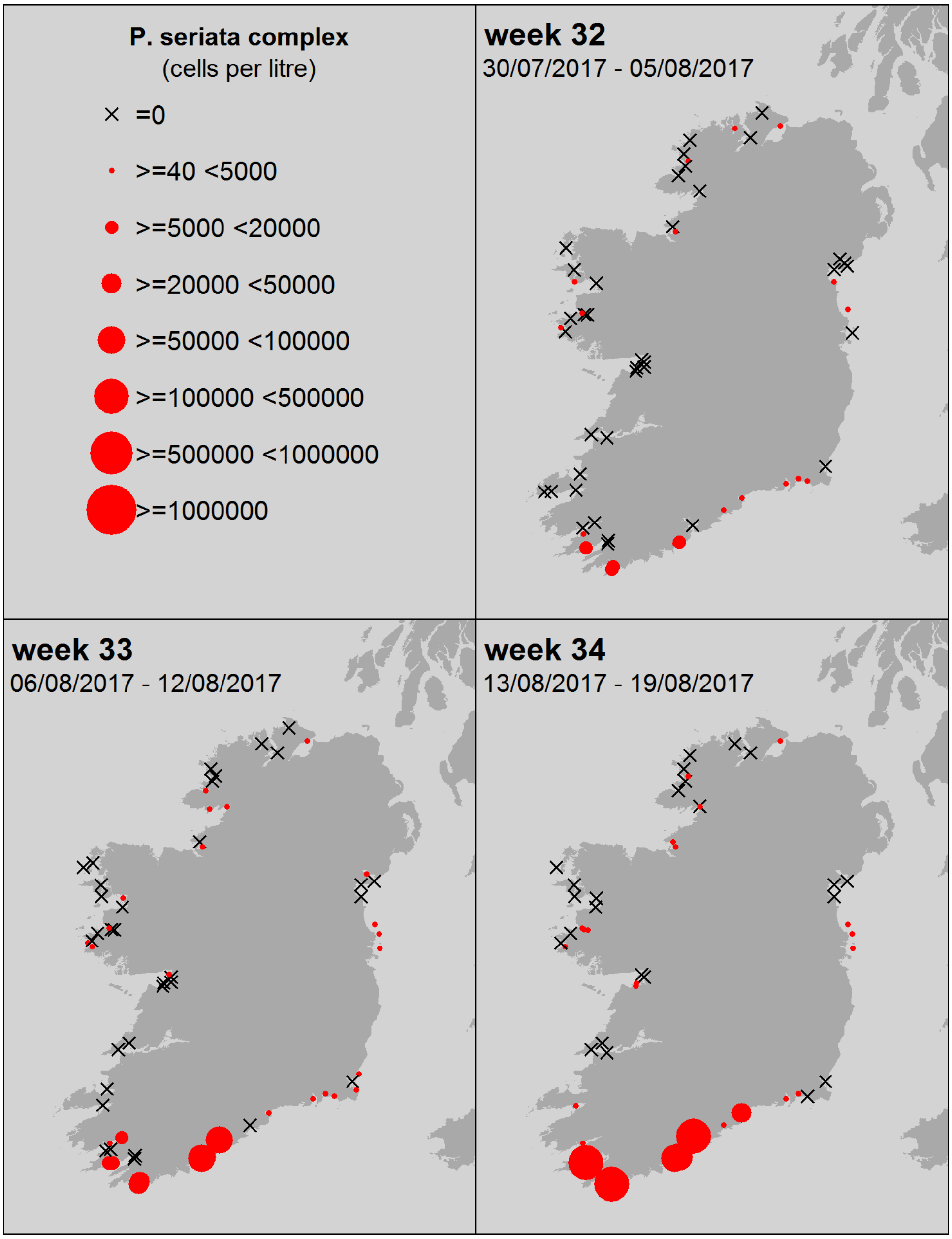


Figure 20. Distribution maps show "Pseudo-nitzschia seriata" complex cell densities at sites/farms in Irish waters over a three week period. Cell densities are plotted as pre-set symbol sizes, colour coded to represent a category of values where x = not detected and red = cell densities. The red circles are further separated into seven categories that denote different cell density ranges.

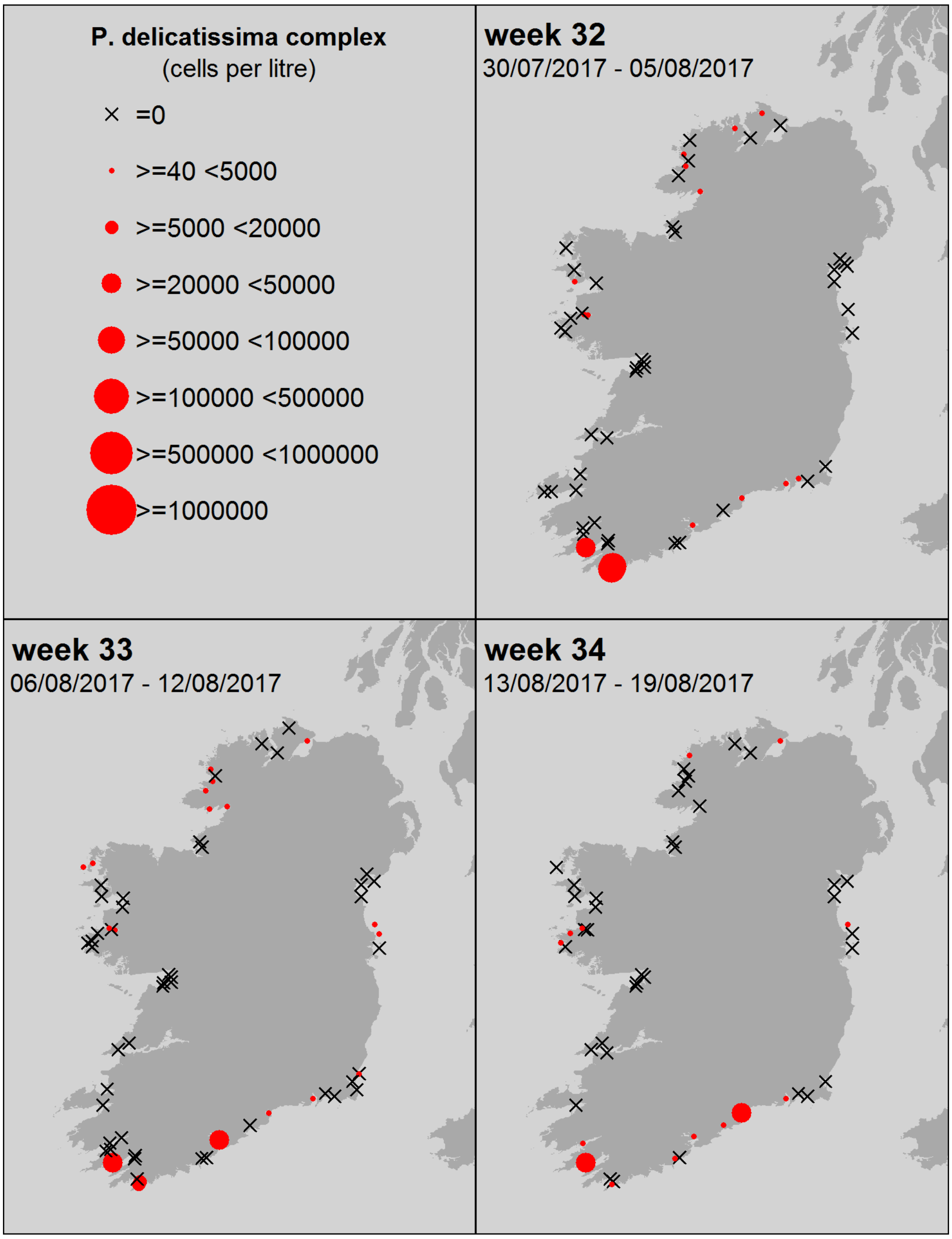


Figure 21. Distribution maps show "Pseudo-nitzschia delicatissima" complex cell densities at sites/farms in Irish waters over a three week period. Cell densities are plotted as pre-set symbol sizes, colour coded to represent a category of values where x = not detected and red = cell densities. The red circles are further separated into seven categories that denote different cell density ranges.

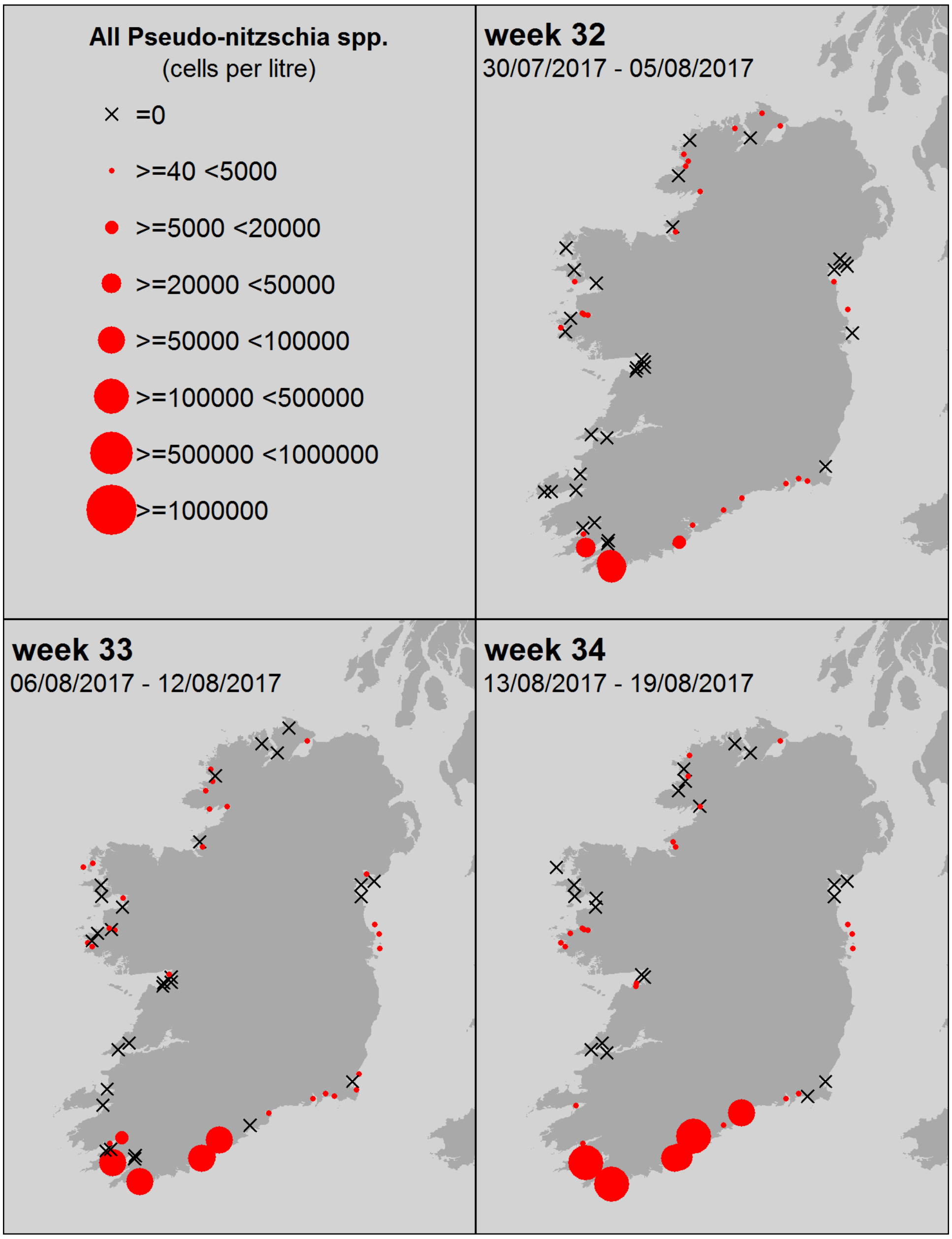


Figure 22. Distribution maps show Pseudo-nitzschia cell densities at sites/farms in Irish waters over a three week period. Cell densities are plotted as pre-set symbol sizes, colour coded to represent a category of values where x = not detected and red = cell densities. The red circles are further separated into seven categories that denote different cell density ranges.

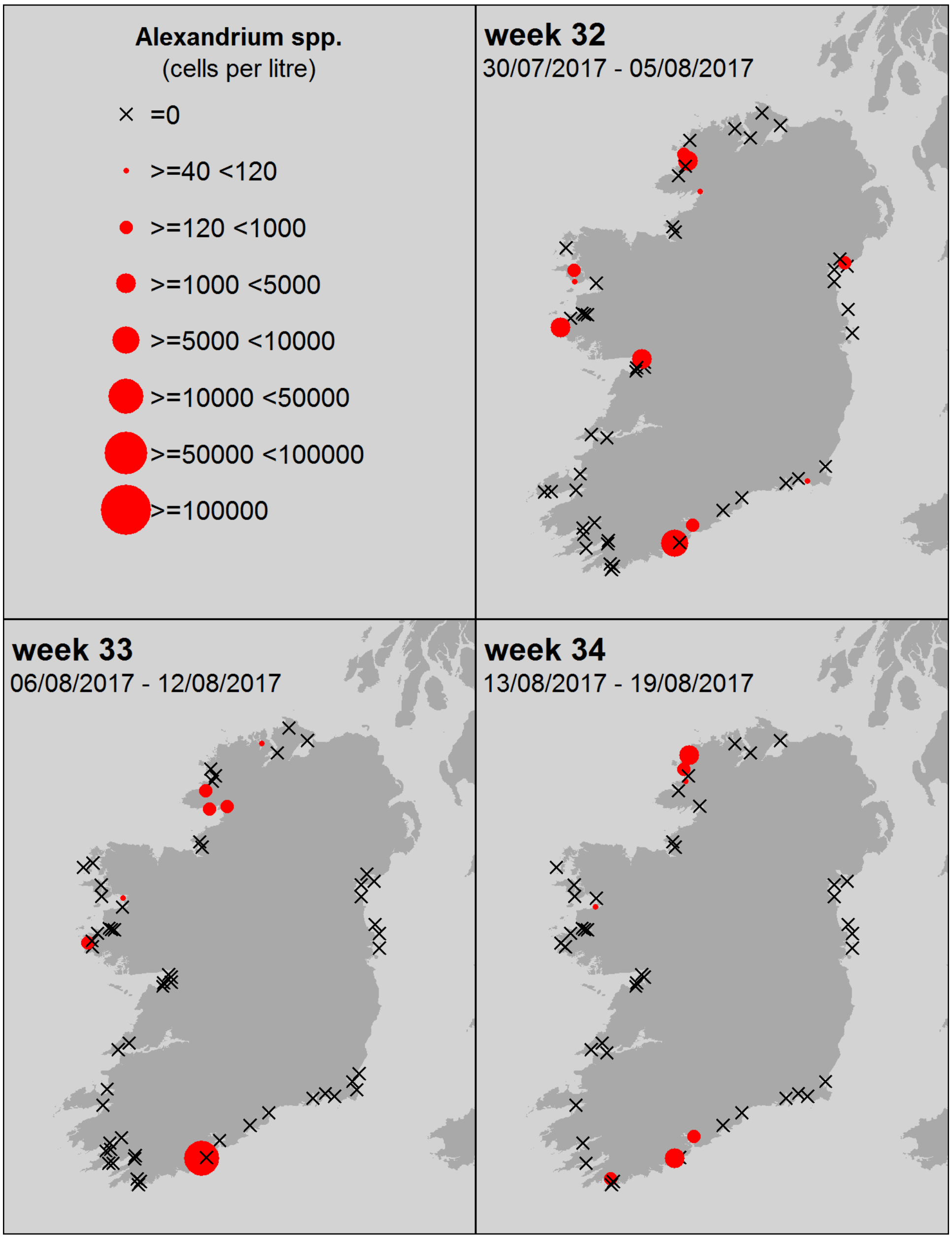


Figure 23. Distribution maps show Alexandrium cell densities at sites/farms in Irish waters over a three week period. Cell densities are plotted as pre-set symbol sizes, colour coded to represent a category of values where x = not detected and red = cell densities. The red circles are further separated into seven categories that denote different cell density ranges.

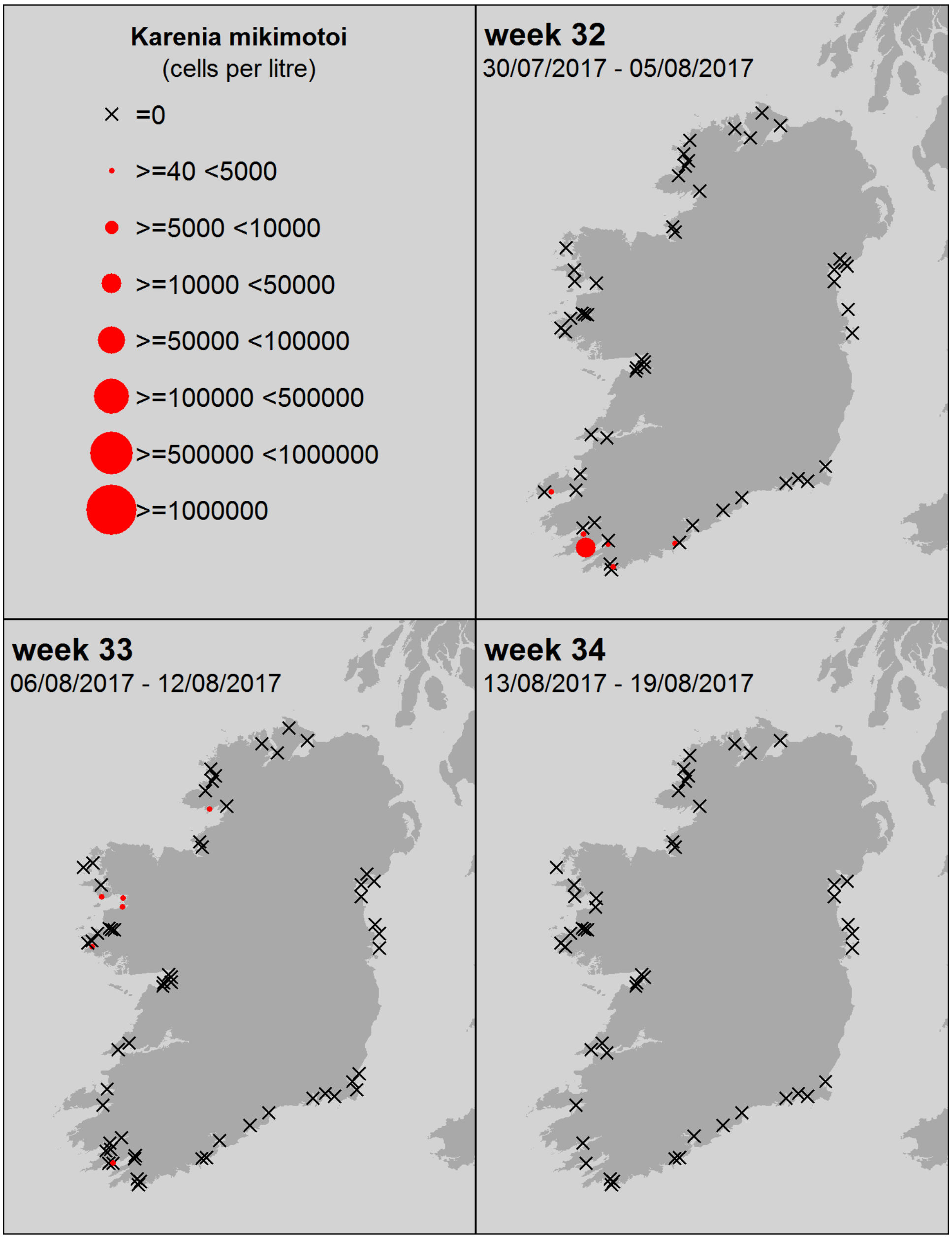


Figure 24. Distribution maps show Karenia mikimotoi cell densities at sites/farms in Irish waters over a three week period. Cell densities are plotted as pre-set symbol sizes, colour coded to represent a category of values where x = not detected and red = cell densities. The red circles are further separated into seven categories that denote different cell density ranges.

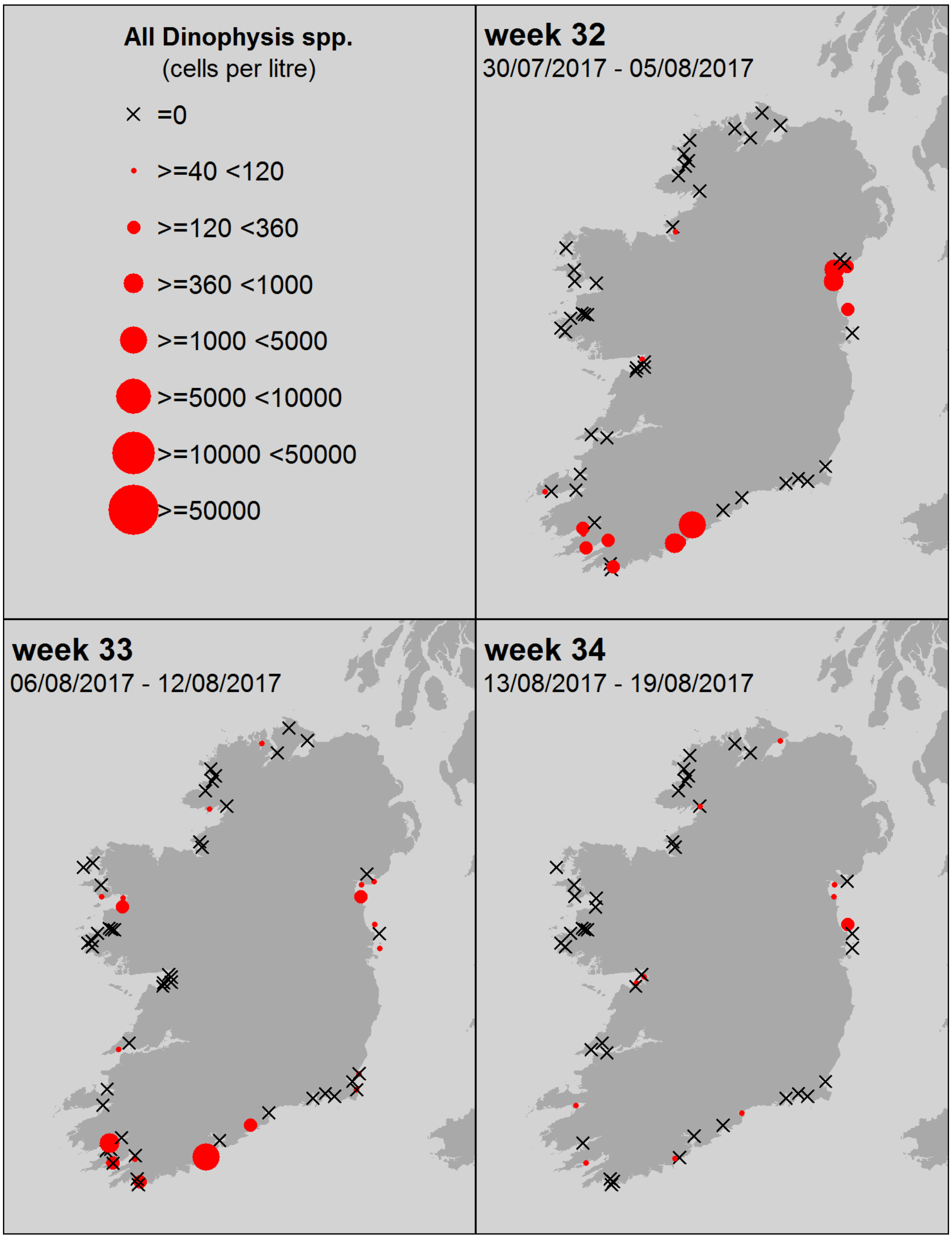


Figure 25. Distribution maps show Dinophysis cell densities at sites/farms in Irish waters over a three week period. Cell densities are plotted as pre-set symbol sizes, colour coded to represent a category of values where x = not detected and red = cell densities. The red circles are further separated into seven categories that denote different cell density ranges.

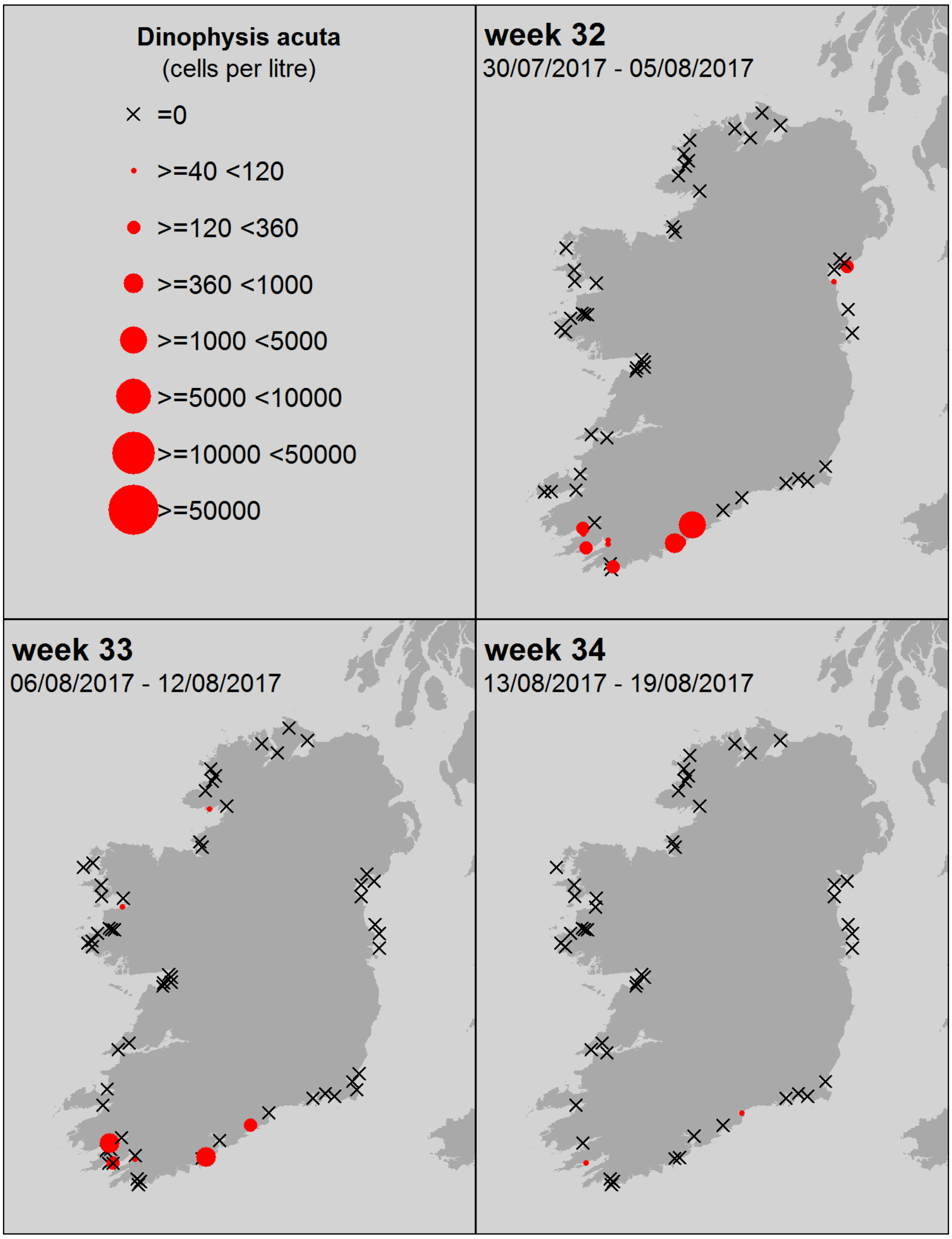


Figure 26. Distribution maps show Dinophysis acuta cell densities at sites/farms in Irish waters over a three week period. Cell densities are plotted as pre-set symbol sizes, colour coded to represent a category of values where x = not detected and red = cell densities. The red circles are further separated into seven categories that denote different cell density ranges.

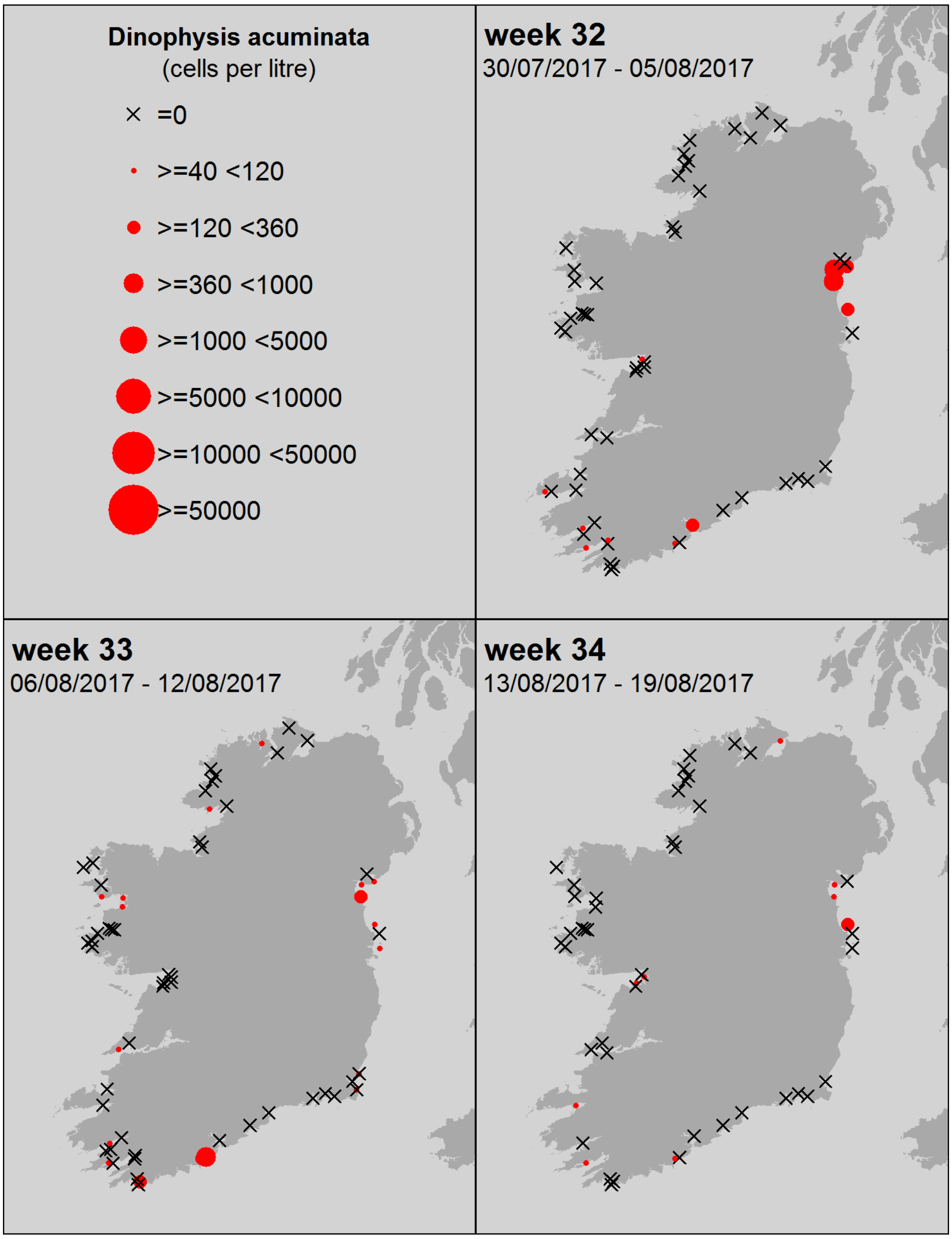


Figure 27. Distribution maps show Dinophysis acuminata cell densities at sites/farms in Irish waters over a three week period. Cell densities are plotted as pre-set symbol sizes, colour coded to represent a category of values where x = not detected and red = cell densities. The red circles are further separated into seven categories that denote different cell density ranges.

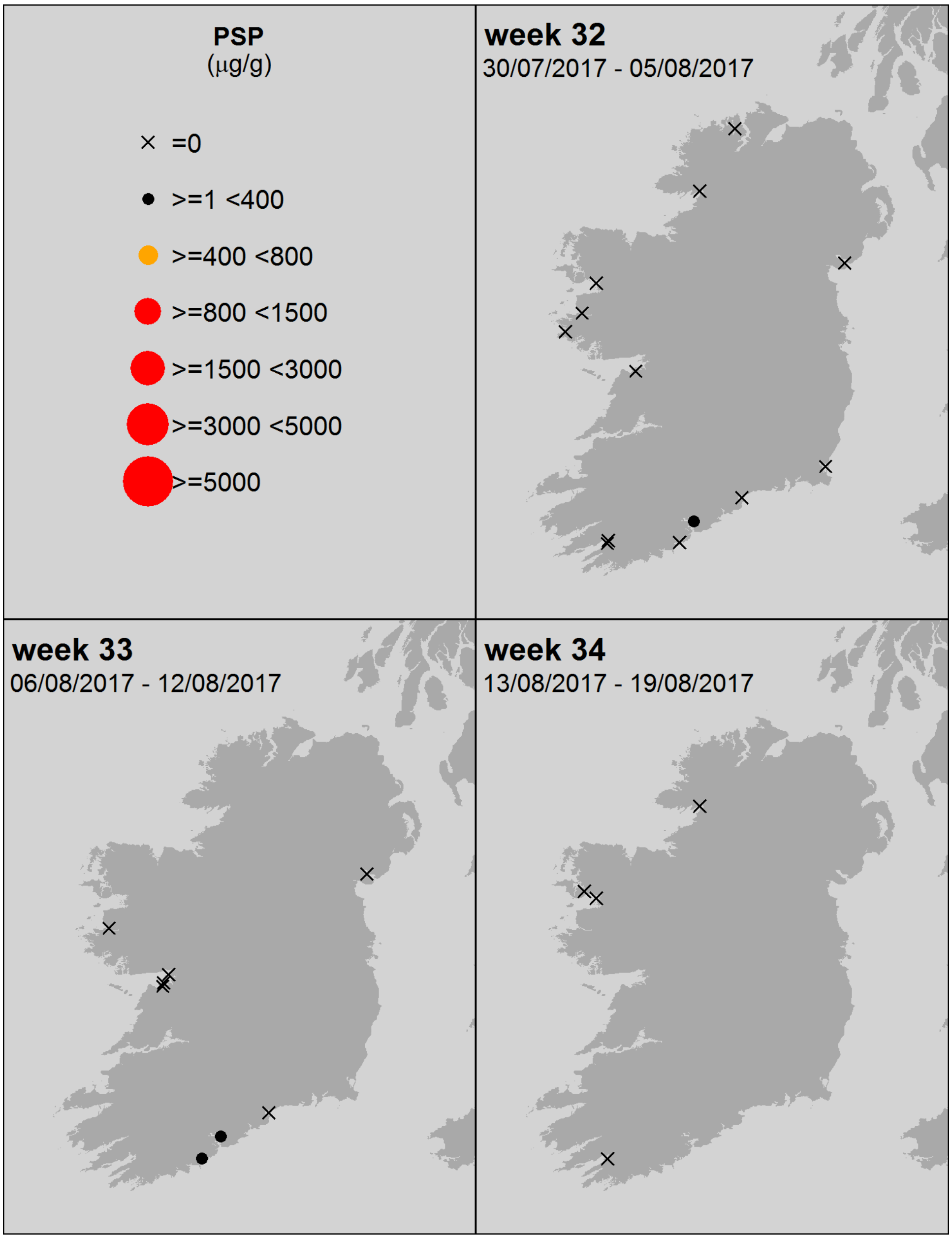


Figure 28. Distribution maps show Paralytic Shellfish Poisoning biotoxin levels at sites/farms in Irish waters over a three week period. Biotoxin levels are plotted as pre-set symbol sizes, colour coded to represent a category of values where x = not detected, black = background levels, orange = warning levels and red = biotoxins levels above the EC Regulation.

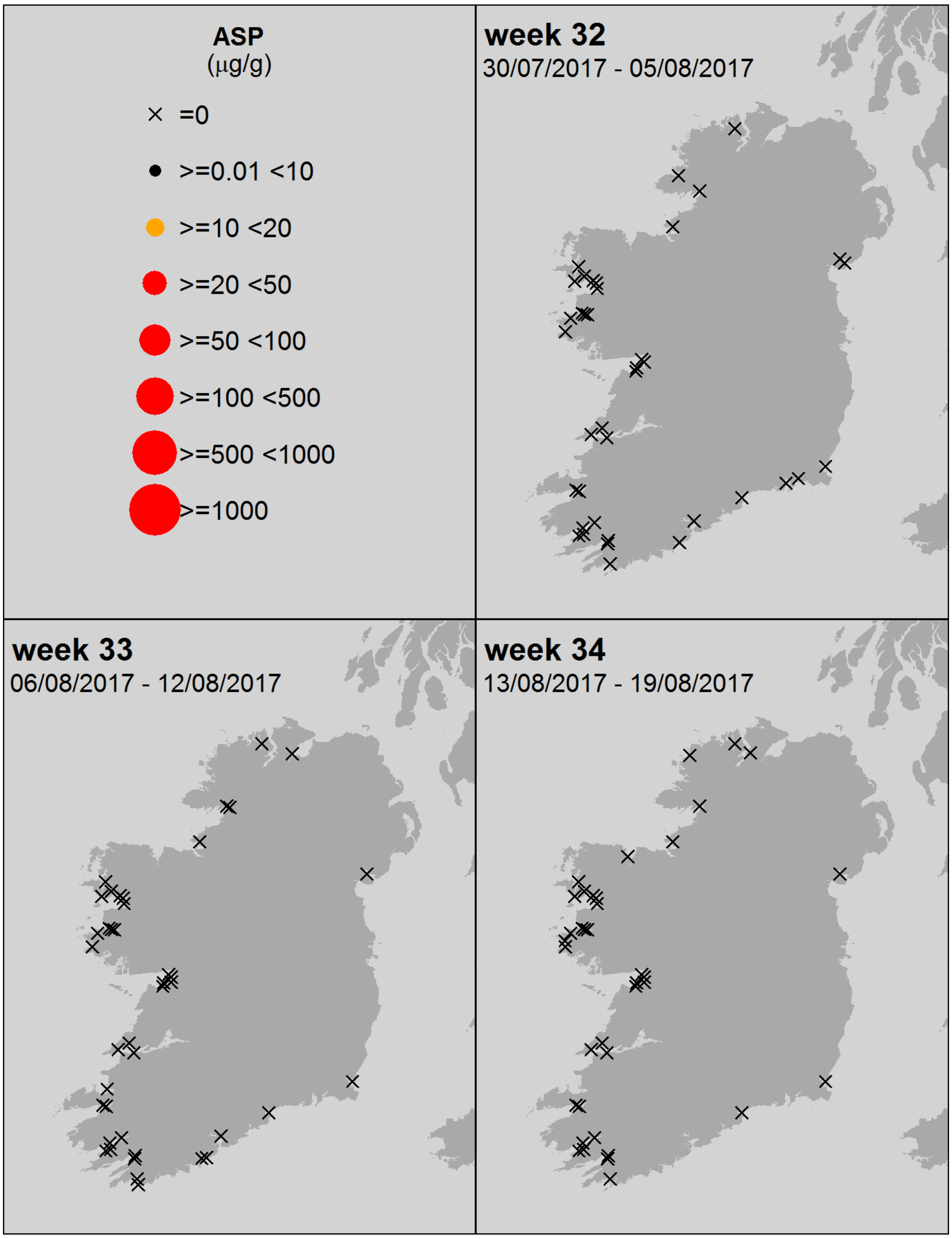


Figure 29. Distribution maps show Amnesic Shellfish Poisoning biotoxin levels at sites/farms in Irish waters over a three week period. Biotoxin levels are plotted as pre-set symbol sizes, colour coded to represent a category of values where x = not detected, black = background levels, orange = warning levels and red = biotoxins levels above the EC Regulation.

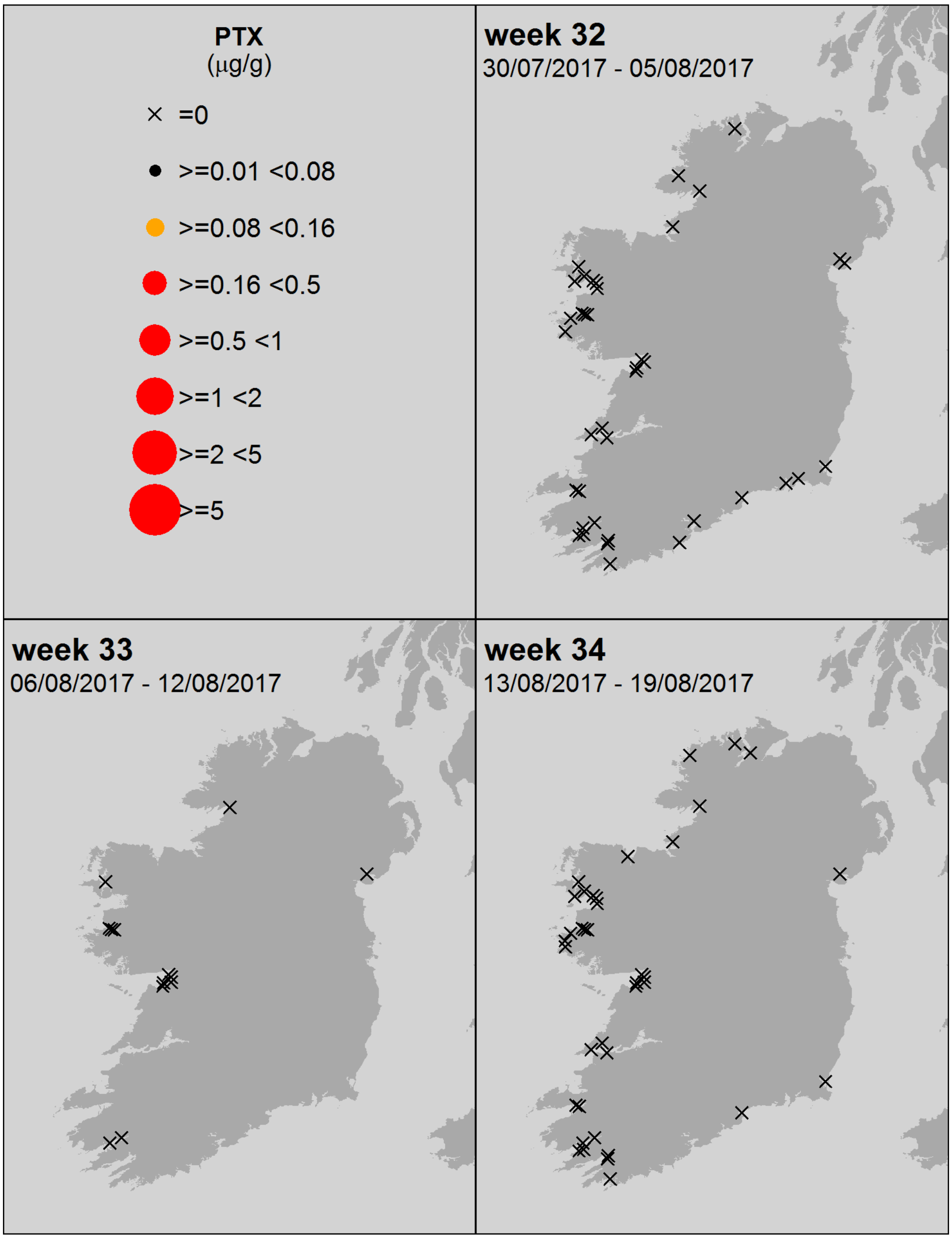


Figure 30. Distribution maps show Pectenotoxin-group biotoxin levels at sites/farms in Irish waters over a three week period. Biotoxin levels are plotted as pre-set symbol sizes, colour coded to represent a category of values where x = not detected, black = background levels, orange = warning levels and red = biotoxins levels above the EC Regulation.

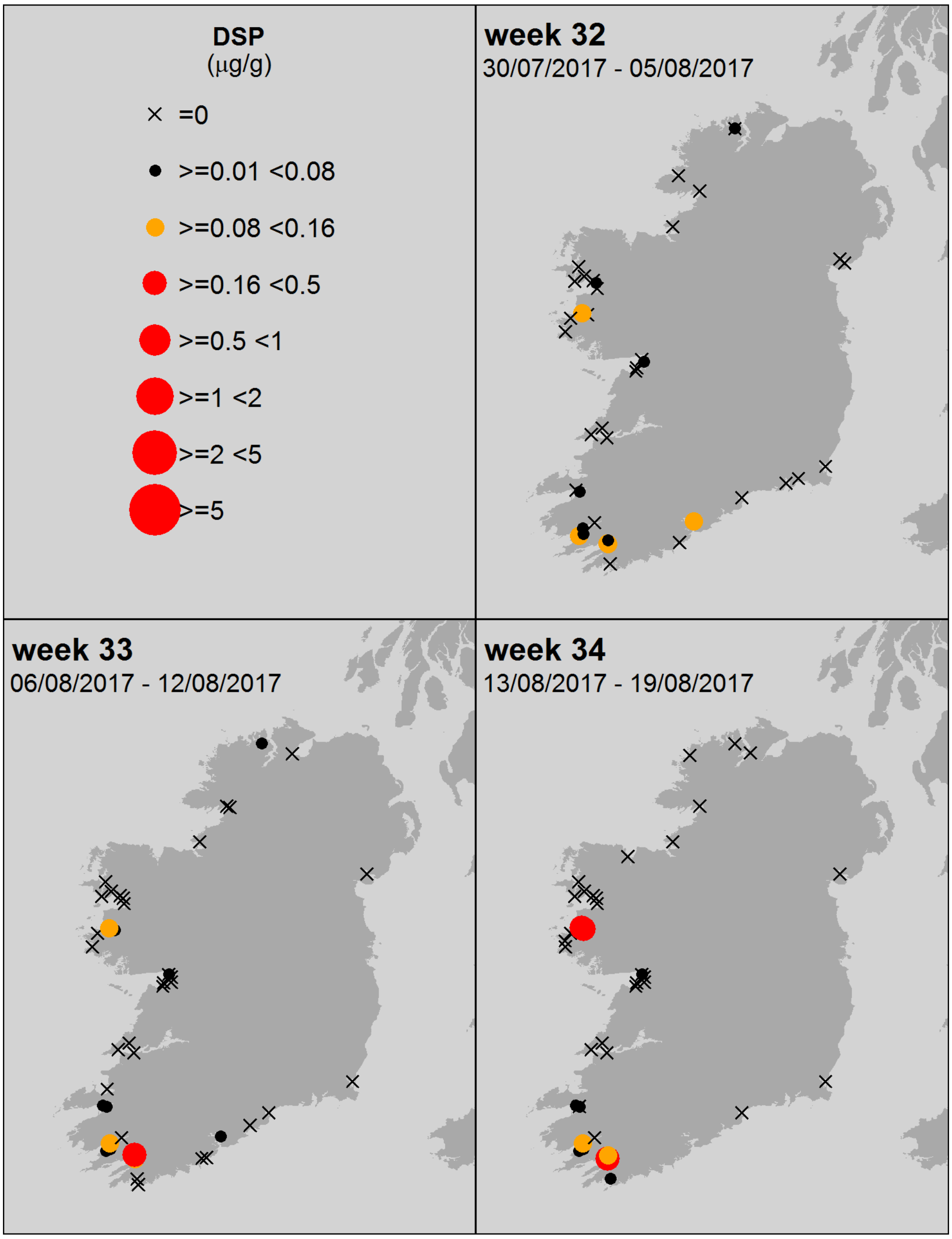


Figure 31. Distribution maps show Diarrheic Shellfish Poisoning biotoxin levels at sites/farms in Irish waters over a three week period. Biotoxin levels are plotted as pre-set symbol sizes, colour coded to represent a category of values where x = not detected, black = background levels, orange = warning levels and red = biotoxins levels above the EC Regulation.

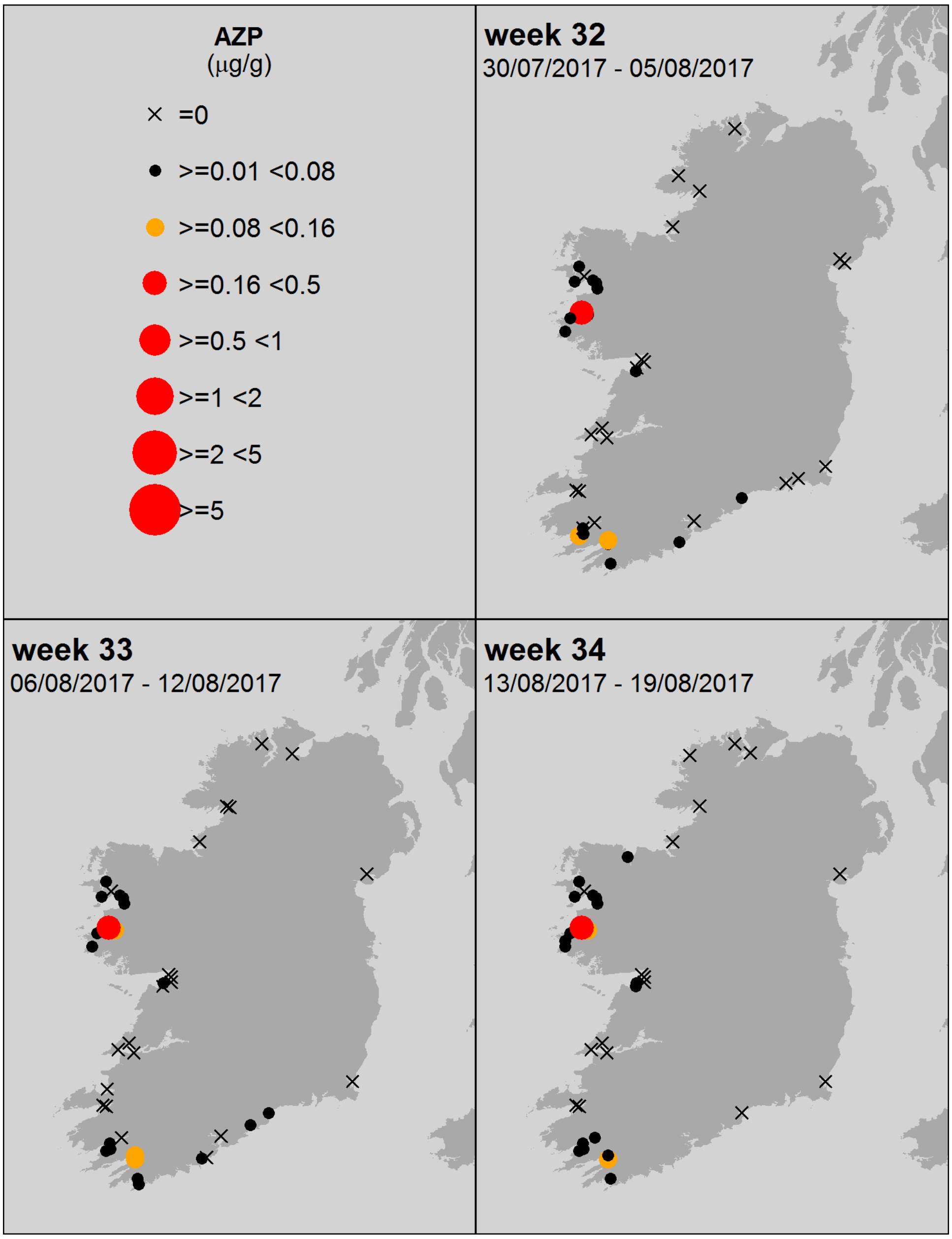


Figure 32. Distribution maps show Azaspiracid Shellfish Poisoning biotoxin levels at sites/farms in Irish waters over a three week period. Biotoxin levels are plotted as pre-set symbol sizes, colour coded to represent a category of values where x = not detected, black = background levels, orange = warning levels and red = biotoxins levels above the EC Regulation.

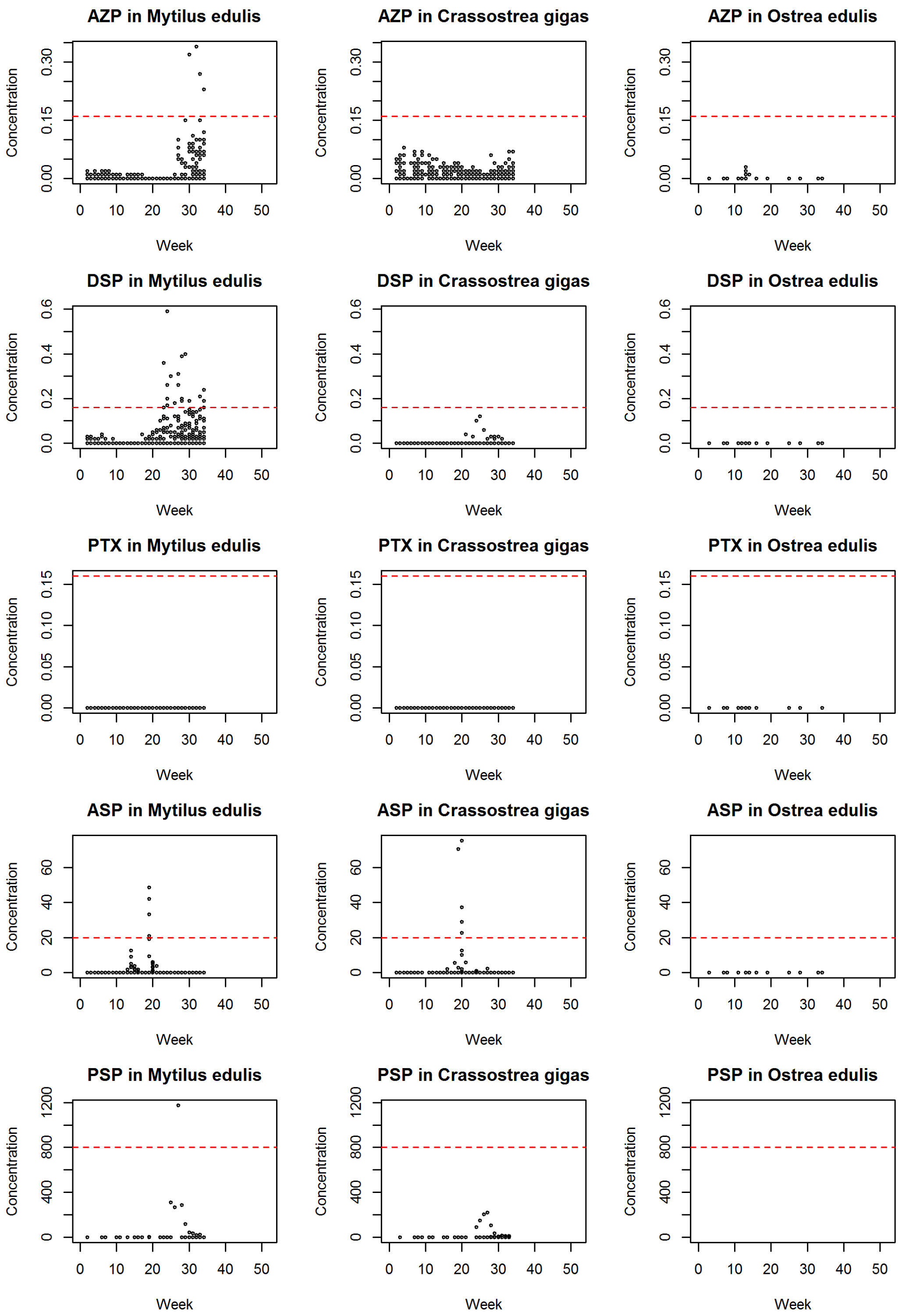


Figure 33. Available weekly national biotoxin levels in the whole flesh of mussels (M. edulis) and oysters (C. gigas and O. edulis). Biotoxin levels tested for include toxins related to Azaspiracid Shellfish Poisoning (the Azaspiracids or AZA toxins), Diarrheic Shellfish Poisoning (the DSP biotoxin Okadaic Acid and dinophysistoxins), Pectonotoxins (the PTX toxins), Amnesic Shellfish Poisoning (the ASP toxins, Domoic Acids) and Paralytic Shellfish Poisoning (the PSP toxin; Saxitoxin group).

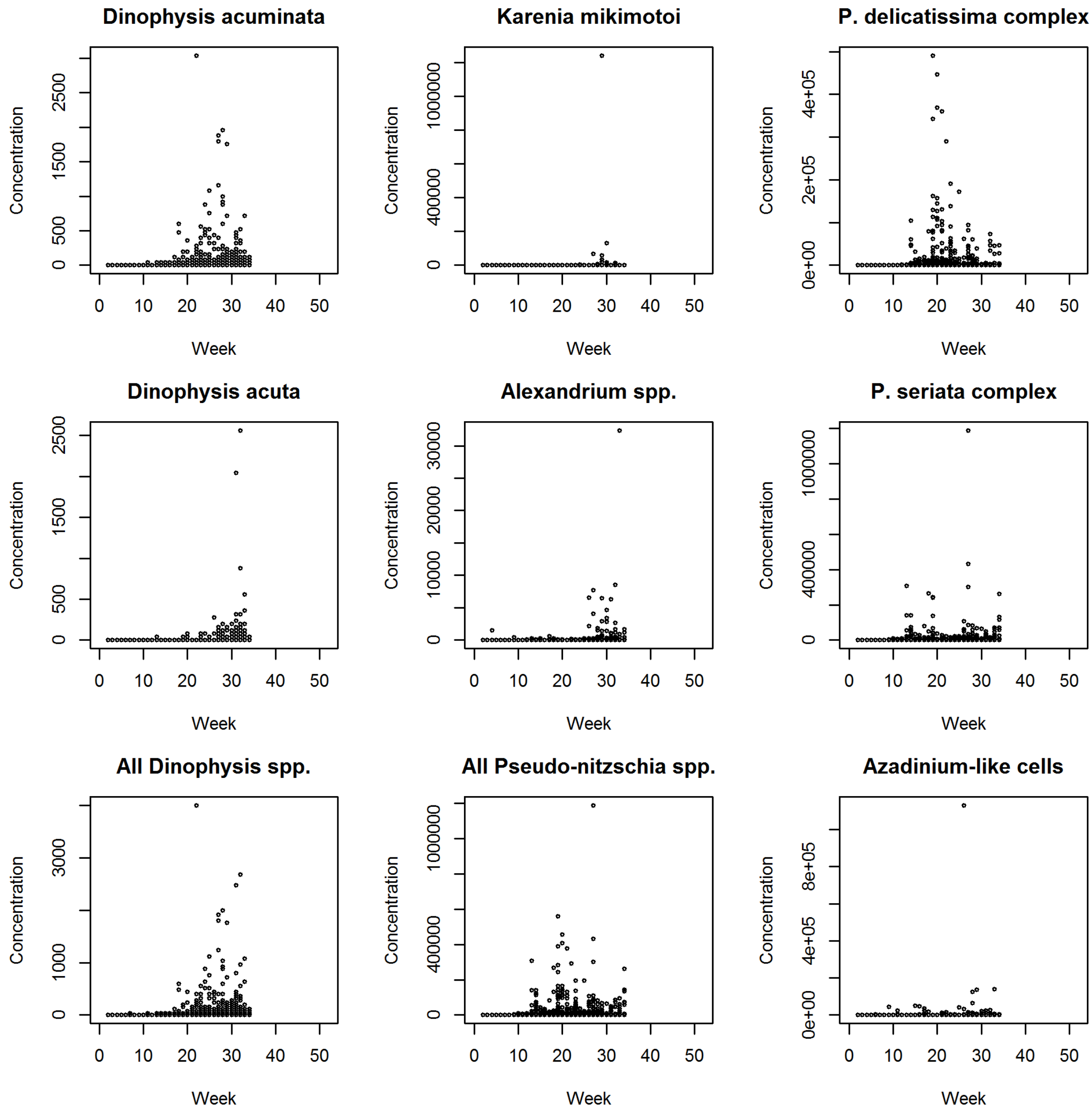


Figure 34. Available weekly HAB (harmful Algal Bloom) cell densities, for the targeted taxa Dinophysis acuminata, Karenia mikimotoi, Pseudo-nitzschia delicatissima complex (< 3 µm size group of the genus Pseudo-nitzschia), Dinophysis acuta, Alexandrium spp., Pseudo-nitzschia seriata complex (> 3 µm size group of the genus Pseudo-nitzschia), All Dinophysis spp., All Pseudo-nitzschia spp., Azadinium-like cells.

Annex 2 Data Product Component Description and Example: Phytoplankton Top 5 species per region Table

Table 1. Top 5 Results from dates between Sunday, August 20, 2017 and Saturday, August 26, 2017

Rank	Region	Species	Actual Count (cells/L)	Rounded Count (cells/L)
1	east	*Skeletonema* spp.	21920	22000
2	east	*Chaetoceros* (Hyalochaete) spp.	12880	13000
3	east	*Chaetoceros danicus*	8640	9000
4	east	*Pseudo-nitzschia seriata* complex	3080	3000
5	east	*Cylindrotheca closterium / Nitzschia longissima*	2800	3000
1	north	*Glenodinium* spp.	2776431	2776000
2	north	*Prorocentrum micans*	23034	23000
3	north	*Skeletonema* spp.	18480	18000
4	north	*Cylindrotheca closterium / Nitzschia longissima*	16338	16000
5	north	Chaetoceros (Hyalochaete) spp.	15000	15000
1	south	*Leptocylindrus minimus*	658875	659000
2	south	*Pseudo-nitzschia delicatissima* complex	123492	123000
3	south	*Paralia* sp.	68080	68000
4	south	*Skeletonema costatum*	40480	40000
5	south	*Skeletonema* spp.	34560	35000
1	southwest	*Asterionellopsis glacialis*	495474	495000
2	southwest	*Skeletonema costatum*	215358	215000
3	southwest	Cyanophyte	131775	132000
4	southwest	*Pseudo-nitzschia seriata* complex	106926	107000
5	southwest	*Skeletonema* spp.	104667	105000
1	west	*Chaetoceros* (Hyalochaete) spp.	153266	153000
2	west	Pennate diatom	84024	84000
3	west	Cilliates	77840	78000
4	west	*Prorocentrum micans*	53682	54000
5	west	*Cylindrotheca closterium / Nitzschia longissima*	25674	26000

Annex 3 Data Product Component Description and Example: Earth Observation satellite derived products

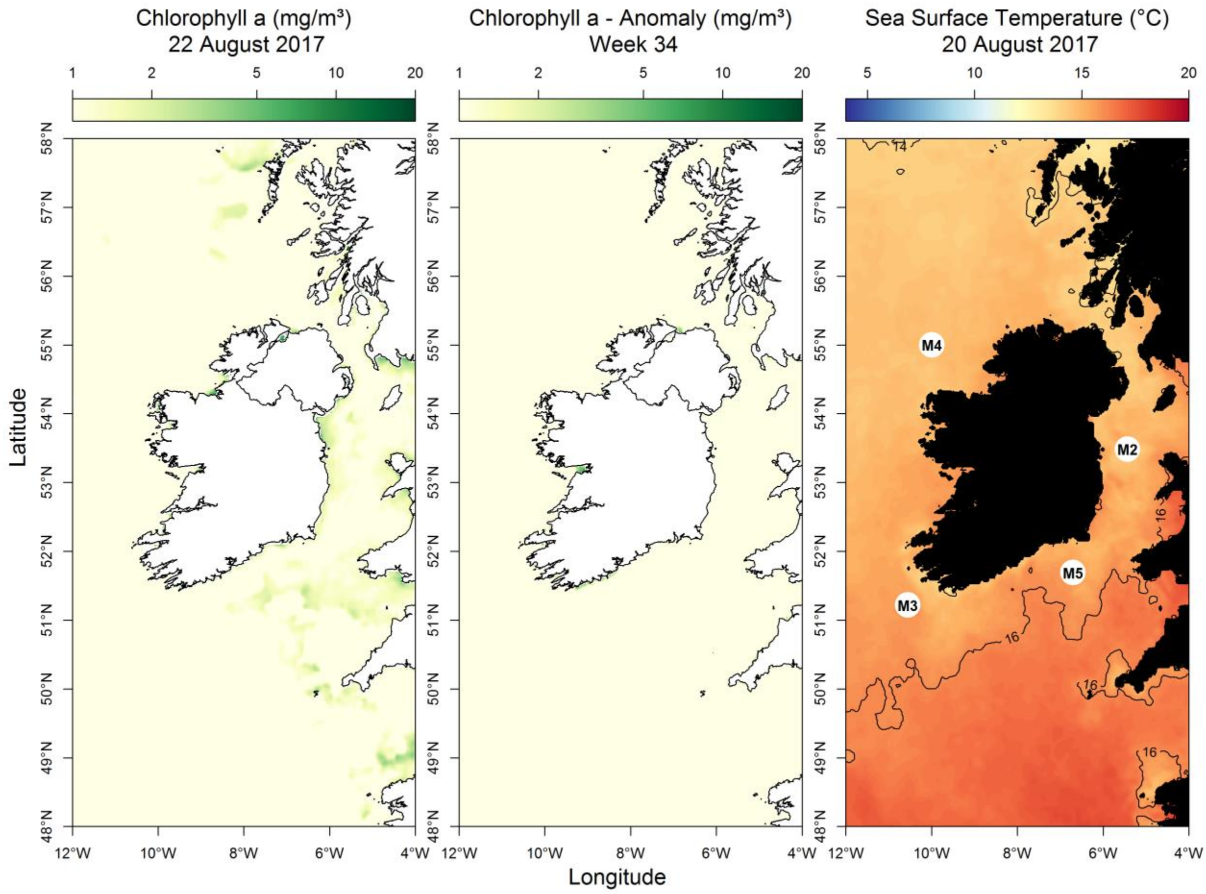


Figure 35. Earth Observation satellite derived chlorophyll a and anomaly, and sea surface temperature is displayed in national spatial maps. The maps show concentrations using a pre-set coloured graduation to represent changing sea surface values of chlorophyll a and SST on a spatial scale.

Annex 4 Data Product Component Description and Example: Data buoys – SST

National weather buoy network: *In-Situ* Sea Surface Temperature levels are measured and collected at fixed points (databuoys) in offshore NE Atlantic waters (databuoy sensor resolution = 0.1 °C; sensor accuracy = +/-0.2 °C; Sampling rate = 10 second average). Data Product: Buoy-derived weekly SST anomalies (departures from a ten year average). The anomaly is the current weekly difference in SST compared to the mean calculated over the last 10 years presented as numeric values in the weekly bulletin (see example below).

No.	File name & Type	Description
1	M3_Tanom_Week_# *.png	*In-situ* SST data anomaly summary from the national M3 weather buoy. SW coast: M3 51° 13N; 10° 33 W
2	M4_Tanom_Week_# *.png	*In-situ* SST data anomaly summary from the national M4 weather buoy. NW coast: M4: 54° 40 N; 09° 04 W
3	M5_Tanom_Week_# *.png	*In-situ* SST data anomaly summary from the national M5 weather buoy. SE coast: M5 51° 41.41N; 06° 42.24W

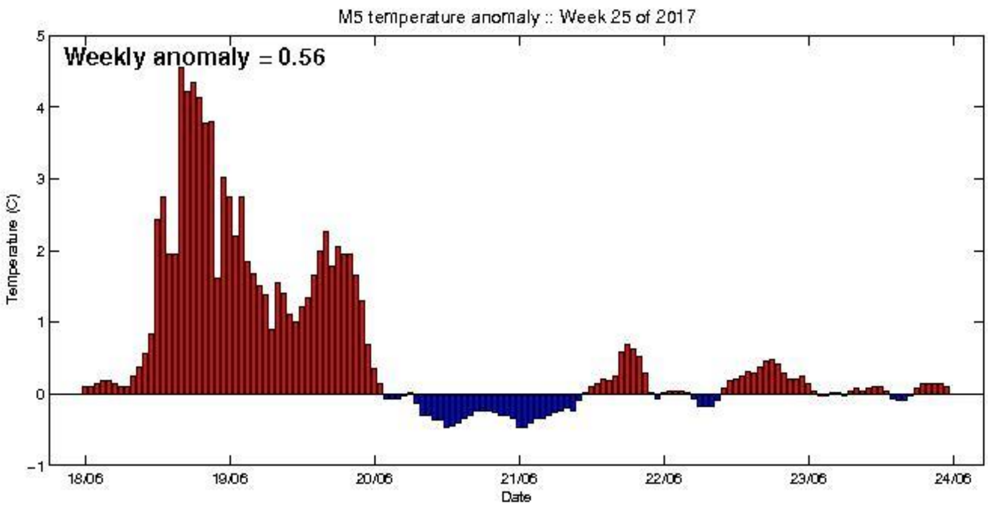


Figure 36. In-situ SST results from the Irish weather buoy network. To complement the SST satellite data, In-situ results from the Irish weather buoy network are used to create a ten year SST anomaly for the week in question. The weekly anomaly is the weekly difference in SST compared to the long term mean for last 10 years. A Matlab script is run to retrieve the data and create the plots (.png). This is a 2017 example for week 35 (17th to 25th June, 2017), data is from the M5 weather buoy (see Figure 35 above for station position).*

Annex 5 Data Product Component Description and Example: Modelled data product examples

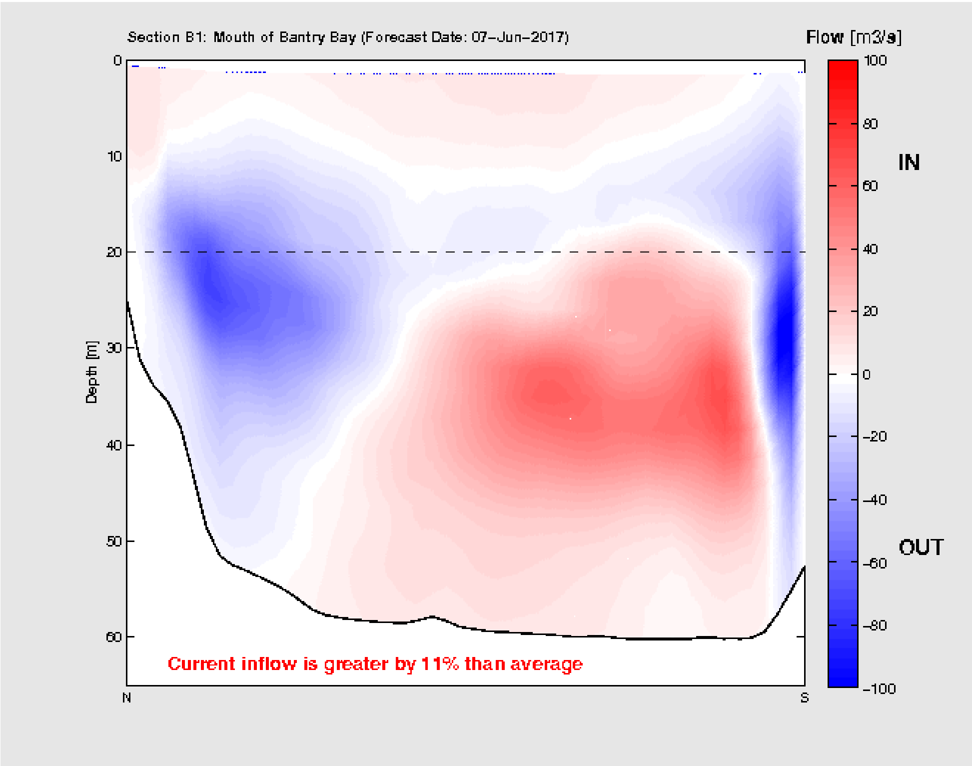


Figure 37. Daily simulated three day temporal average volumetric flux (m3.s-1) forecasts fat the mouth of Bantry Bay. This is one example of a number of transects where physical conditions are simulated, extracted and plotted on a daily operational basis to present local oceanographic phenomenon (e.g. advection of offshore waters into a bay) in the local area of interest.

(a)

(b)

(c)

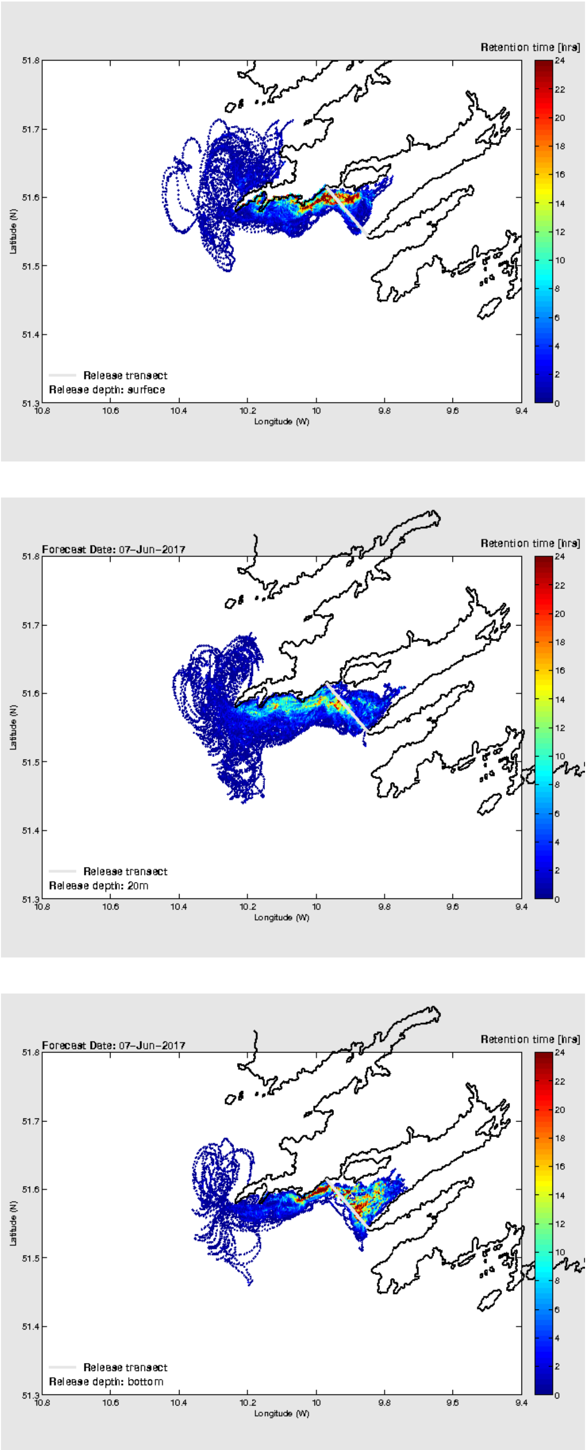
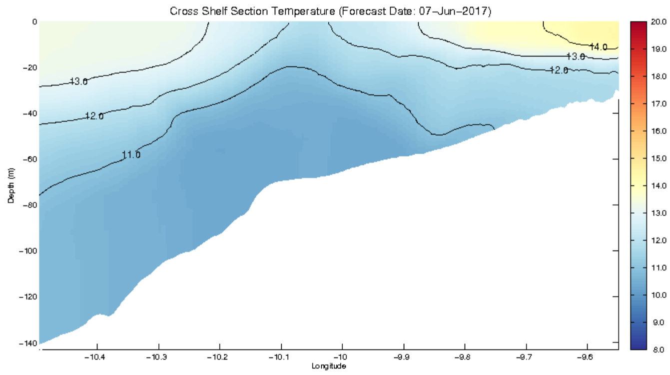
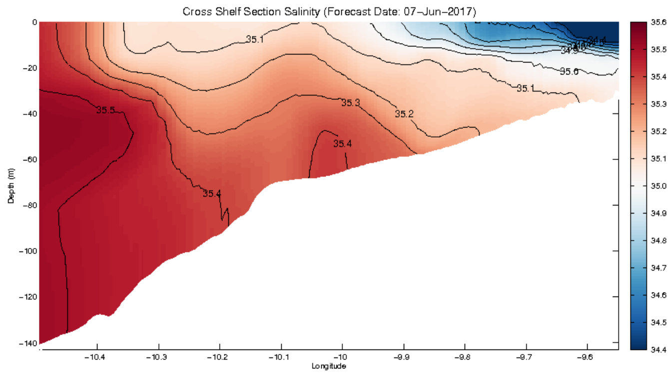


Figure 38. Particle tracking: Aerial view of simulated three day temporal average projected water movements off southwest Ireland. Three water levels (a= surface, b = 20 m and c = bottom waters) from the model are presented. The colour scale relates to the average time, in hours, that particles are retained and the likely distance particles may travel along the projected pathway displayed. In other words, reddish colours represent areas where particles remain longest while cooler colours represent areas where particles remain for shorter periods.

(a)



(b)



(c)

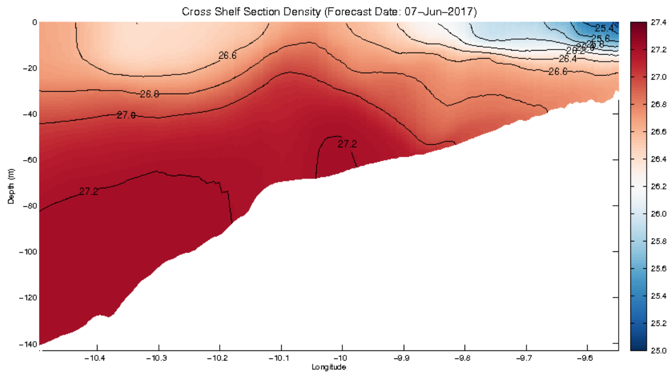


Figure 39. Model simulated (a) temperature (°C), (b) salinity and (c) density σt (kg.m-3) along a southwest – northeast transect from 10° 30' W (0 km) on the continental shelf to inner Bantry Bay (70+ Km). This is one example of a number of transects where physical conditions are simulated, extracted and plotted on a daily operational basis to present local oceanographic phenomenon e.g. upwelling events in the local area of interest.

List of Figures